ELEMENTARY COURSE OF INSTRUCTION FOR MINE FOREMEN AND PIT BOSSES

DAVIS

AN ELEMENTARY COURSE OF INSTRUCTION

...FOR...

Mine Foremen and Pit Bosses.

...BY...

FLOYD DAVIS, E. M., PH. D.,

President of the Board of Examiners for State Mine Inspectors of Iowa.

PUBLISHED BY THE

Western Correspondence School of Mining Engineering,

DES MOINES, IOWA.

1901.

PRESS OF F. R. CONAWAY,
DES MOINES.

PREFACE

The law of several states requiring mine foremen and pit bosses to be examined in order to continue in their work has created a demand for instruction in the practical lines upon which the various examining boards make their tests. It has also stimulated a desire in many men to make the best of the opportunities that are afforded for personal advancement. The mechanical drudgery that surrounds every miner who works only with his hands cannot be eliminated until he educates his brain to direct the labor and thus draw success from its intellectual fountains. Every miner should be ambitious to advance to the position of foreman; every foreman should strive to become a superintendent; every superintendent should aim for a managership; and every manager should hope to become a mine owner. Such advancement has been realized thousands of times by those who have worked and studied for the promotion, and it is hoped that these lessons may be of some service in preparing men to accomplish these results.

This book is written to meet the demands for such instruction, and especially for the laboring man who is ambitious to advance to something better than his hands alone can afford. It is not filled with theories of untried processes, but the material it contains is the result of the best practice, and just what every man engaged in coal mining should be familiar with. It is thoroughly up-to-date and adapted to practical mining as conducted in the central west. It is made brief in order that it may be read by those whose time is limited, and its language is intended to be clear, forcible and easily understood. The course is made sufficiently technical to furnish an introduction to the professional knowledge required for actual work, and it is believed that mining men can derive much benefit by a careful study of its pages. It is not, however, intended to take the place of a course in a technical or correspondence school, because thorough instruction in such an institution cannot be equaled in any other way, on account of the advantages there offered in criticising the student's work.

This course is well-arranged for those who wish to prepare for examinations, and it covers the essential topics required by the various examining boards. The work begins at the very threshold of the profession where assistance is most needed by miners, and all who can read, write and have begun the study of mathematics are prepared for it. The greatest deficiency with miners is their lack of knowledge of mathematics as applied to mining problems, and in the preparation of this book every effort has been made to present the most essential subjects in the least difficult manner. It begins with the elements of arithmetic, and anyone who will apply himself can understand and succeed with the work. The instructional part consists of 252 questions and answers, and each lesson is of such length that an average person can easily master it in a few hours conscientious study. The time required, however, depends on the reader's ability, his previous knowledge of the subject, his habits of study and the manner in which he concentrates his thoughts on the work. Every question is answered in a concise and clear manner, and for the purpose of giving practice, a series of 260 questions are added of a somewhat different nature from those discussed, but which can be answered from the information given in the lessons.

In preparing this book, the principal works on coal mining have been freely consulted, including the writings of Pameley, Wardle, Mauchline, Farley, Tate, Atkinson, Hopton and others. The questions given by various state examining boards have been carefully consulted, and the mining reports and geological bulletins of the various coal mining states have been of much service in furnishing information of local methods of work. The author has compiled the best material from these various sources in accordance with his own experience and observation in the field, and believes that it will fully meet the demands of all miners for an elementary course of instruction.

Des Moines, Iowa, July, 1901.

CONTENTS

CHAPTER I.—ARITHMETIC.

LESSON I.

Definitions and Signs.

Q. 1. What is arithmetic, and what are the fundamental operations belonging to it?

A. Arithmetic is the science of numbers, or the art of computation, and its fundamental operations are notation and numeration, addition, subtraction, multiplication and division.

Q. 2. What is meant by notation and numeration, and what signs are used in connection with them?

A. Notation is expressing numbers by figures, while the reading of figures is called numeration. The sign used with whole numbers is the comma (,), and expresses units of the same general name, which are read together. Thus the number 37,210,303 should be read thirty-seven million, two hundred and ten thousand, three hundred and three. The comma should always be used in writing numbers greater than 999.

A decimal is a fractional part of a unit expressed on a scale of tenths, hundredths, thousandths, etc. The period (.) is used to express this, and indicates that the number following is a decimal. Thus the number 221,689,926.320 is read two hundred and twenty-one million, six hundred and eighty-nine thousand, nine hundred and twenty-six, and three hundred and twenty thousandths. By replacing the period with a comma, the number is increased a thousand fold.

Q. 3. What is meant by addition, and what sign is used to express it?

A. Addition is the process of finding the sum of two or more numbers. The vertical cross (+), commonly called plus, when placed between numbers, indicates that they are to be added. Thus 2+8+12 is read 2 plus 8 plus 12.

Q. 4. What is meant by subtraction, and what sign is used to express it?

A. Subtraction is the process of finding how much greater one number is than another. A short, horizontal line (—), commonly called minus, when placed between numbers indicates that the number after it is to be subtracted from the one before it. Thus $8-4$ is read 8 minus 4.

Q. 5. What is meant by multiplication, and what sign is used to express it?

A. Multiplication is the process of taking a given number as many times as there are units in another. The oblique cross ($\times$) when placed between numbers indicates that they are to be multiplied. Thus 9×3 is read 9 multiplied by 3.

Q. 6. What is meant by division, and what sign is used to express it?

A. Division is the process of finding how many times one number is contained in another. A short, horizontal line with a point above and below it ($\div$) when placed between numbers indicates that the number before it is be divided by the number after it. Thus $20\div5$ is read 20 divided by 5. This form of expression is equivalent to placing the number to be divided above and the number to divide by below a horizontal line. Thus $\frac{20}{5}$ is also read 20 divided by 5.

Q. 7. What is the sign of equality, and how is it used?

A. The sign of equality is two short, horizontal lines ($=$), and indicates that the numbers, or combination of numbers, connected by it are equal. Thus $15+7=24-2$ is read 15 plus 7 is equal to 24 minus 2. Again $\frac{20\times5}{4}=25$ is read 20 multiplied by 5 and divided by 4 is equal to 25. Such expressions are called equations.

Division.

Q. 8. What names are applied to the numbers used in division?

A. The dividend is the number to be divided. The divisor is the number to divide by. The quotient is the result obtained by the process of division. When the dividend does not contain the divisor an exact number of times, the part of the dividend left is called the remainder, and is always less than the divisor.

Q. 9. What are the two methods of division called, and what is the distinction between them?

A. When the operation of multiplication and subtraction involved in division is so simple and easy that it can be performed mentally, the process is called short division, but when it is so complex that it has to be written in full, the process is known as long division. In all other respects short and long division are the same.

Q. 10. What is the quotient obtained by dividing 38,408 by 8?

A.
$$8\overline{)38{,}408}$$
$$4{,}801$$

It is customary to write the divisor to the left of the dividend, separated from it by a curved line, and the quotient underneath the dividend, separated from it by a horizontal line. 8 is not contained in 3, so we take 38 as the least partial dividend in which it is contained. It goes into this number 4 times, with a remainder of 6. The 6 being in the tens column ahead of the next figure makes this 64, and 8 is contained in this 8 times, with no remainer. Into 0, 8 goes no times, and into 8 it goes once. Thus the quotient is 4,801.

Q. 11. A mine operator has a contract to deliver 650 tons of lump coal each day. In the operation of the mine, 230 tons of screenings are obtained and 40 tons of coal are wasted daily. How many miners must be employed to produce this amount, if they average 4 tons each daily?

A. The total amount of coal to be mined each day will be 650 + 230 + 40 tons = 920 tons. Then if each miner averages 4 tons per day, there will be required as many miners as 4 is contained in 920.

$$4\overline{)920}$$
$$230.$$

The number of miners required will, therefore, be 230.

Q. 12. What is the quotient obtained by dividing 22,872 by 42?

A.
$$\begin{array}{r} 42)22{,}872(544\tfrac{24}{42} \\ \underline{21\ 0} \\ 1\ 87 \\ \underline{1\ 68} \\ 192 \\ \underline{168} \\ 24 \end{array}$$

As neither 2 nor 22 will contain the divisor, we take 228 as the first partial dividend. 42 is contained in this 5 times, which number

is written to the right as the first partial quotient. The divisor multiplied by this gives 210, which is written under the 228 and subtracted from it, leaving 18 as the remainder. To this we annex the next figure of the dividend and thus form 187 as the second partial dividend. 42 is contained in this 4 times, and 4 times 42 is 168, which, subtracted from 187, leaves 19. To this remainder bring down the last 2 of the dividend and we have 192 as the last partial dividend. 42 is contained in this 4 times, and 4 times the divisor is 168. Subtracting this from the 192 leaves as a final remainder 24, which should be written over the divisor in the quotient, thus completing the division.

Q. 13. The circle described by the crank pin of an engine is 62 inches. How many revolutions must the pin make to travel a distance of 434 feet?

A. 434 feet is reduced to inches by multiplying it by 12. Thus $434 \times 12 = 5{,}208$, the number of inches traveled by the piston crank. This, divided by the number of inches it describes in each revolution, will give the number of revolutions required.

$$
\begin{array}{r}
62)5{,}208(84 \\
4\ 96 \\
\hline
248 \\
248 \\
\hline
\end{array}
$$

Q. 14. The gross annual receipts of a certain coal mining company in 1900 were $146,485, and the expenses of operating the mines were $102,320. What was the average daily income of the company, the mines being worked every day in the year?

A. $146,485—$102,320=$44,165 as the net annual income. Now, as this was divided equally among the 365 days of the year, the profits of each day were as many dollars as 365 is contained in 44,165, which is

$$
\begin{array}{r}
365)44{,}165(121 \\
36\ 5 \\
\hline
7\ 66 \\
7\ 30 \\
\hline
365 \\
365 \\
\hline
\end{array}
$$

The answer is, therefore, $121

NOTE—Questions 10 and 11 are solved by short division; 12, 13 and 14 by long division.

LESSON II.

Fractions and Decimals.

Q. 15. What is meant by a common fraction?

A. A common fraction is a part of a number, as one-half, one-third, etc. Two numbers, called the numerator and the denominator, are required to express it. The former is placed above a horizontal line and expresses how many equal parts of a whole number are taken, while the latter is placed below the same line and denotes the number of parts into which the number is divided. Thus the fraction $\frac{5}{9}$ denotes that the number is divided into 9 equal parts, and that 5 of these are taken.

Q. 16. What is meant by a proper fraction? What by an improper fraction? What by a mixed number?

A. When the numerator is less than the denominator, the expression is called a proper fraction, and its value is less than unity. When the numerator is greater than the denominator, the expression is called an improper fraction. When an improper fraction is reduced to its simplest form, it becomes a mixed number, which is a whole number combined with a fraction. Thus $\frac{3}{4}$ is a proper fraction. $\frac{4}{3}$ is an improper fraction, and if reduced to its simplest form becomes $1\frac{1}{3}$, which is a mixed number.

Q. 17. What are some of the general principles of common fractions?

A. Multiplying the numerator multiples the fraction, and dividing the numerator divides the fraction. Multiplying the denominator divides the fraction, and dividing the denominator multiplies the fraction. Multiplying or dividing both terms of the fraction by the same number does not alter the value of the fraction. Hence it follows that any change in the numerator produces a like change in the value of the fraction, but a change in the denominator produces an opposite change in the value of the fraction.

Q. 18. In what three ways may decimal fractions be expressed?

A. Decimal fractions may be expressed by words, as one-tenth, twelve hundredths, etc.; by writing in the form of common fractions, as $\frac{1}{10}$, $\frac{12}{100}$, etc.; and by writing as decimals, as .1, .12, etc. The term decimals is properly called decimal fractions, because the denominator is understood.

Q. 19. What are some of the general principles of decimal notation and numeration?

A. When a decimal is expressed as a common fraction, the denominator is 10 or some multiple of 10, which is unity with as many ciphers annexed as there are places in the decimal. But when expressed in decimal notation, each figure is given its local value by prefixing ciphers when necessary, and then placing the decimal point before the first figure. The value of the numerator is determined as with integers, but the denominator is determined by numerating from the decimal point. The decimal is then read as a whole number, and its name is derived from its lowest decimal unit or right hand figure. Thus eight-tenths is written .8; seventy-five hundredths is written .75; eight hundred and twenty thousandths is written .820; and seventy-five ten thousandths is written .0075.

Q. 20. How can a common fraction be reduced to a decimal?

A. A common fraction can be reduced to a decimal by annexing ciphers to the numerator, dividing by the denominator, and then point off as many decimal places in the quotient as there are ciphers annexed.

Thus $\frac{3}{4} = 4\overline{)3.00}$ $.75$ Again $\frac{5}{8} = 8\overline{)5.000}$ $.625$

Q. 21. How can a decimal be reduced to a common fraction?

A. A decimal can be reduced to a common fraction by omitting the decimal point, supplying the proper denominator, and then reduce to lowest terms by dividing both numerator and denominator by the same number. Thus $.450 = \frac{450}{1000} = \frac{45}{100}$.

Addition of Fractions and Decimals.

Q. 22. What rules can be given for the addition of fractions and decimals?

A. Reduce the fractions to a common denominator. Then add the numerators together and place the sum over the common denominator. Thus since the common denominator of $\frac{1}{2}$, $\frac{1}{3}$ and $\frac{1}{4}$ is 12, their

sum may be expressed $\frac{6}{12}+\frac{4}{12}+\frac{3}{12}=\frac{13}{12}$ or $1\frac{1}{12}$. With decimals, place the numbers so that the decimal points shall stand directly under each other. Then add them together and place the decimal point directly under the points in the numbers added. Thus the sum of .130, .786, and 4.321 is

$$\begin{array}{r} .130 \\ .786 \\ 4.321 \\ \hline 5.237 \end{array}$$

Subtraction of Fractions and Decimals.

Q. 23. How do you proceed to subtract fractions and decimals?

A. Reduce the fractions to a common denominator. Then subtract the numerator of the subtrahend from the numerator of the minuend, and place the difference over the common denominator. Thus $\frac{5}{8}-\frac{1}{2}=\frac{5}{8}-\frac{4}{8}=\frac{1}{8}$. With decimals, place the subtrahend directly under the minuend, as in the addition of decimals, subtract as in whole numbers, and place the decimal point directly under the points of the numbers employed. Thus 5.234—2.107 equals

$$\begin{array}{r} 5.234 \\ 2.107 \\ \hline 3.127 \end{array}$$

Q. 24. A farmer buys $102\frac{4}{5}$ acres of land at one time, 72.46 acres at another, and 31.50 acres at another. From this tract he sells 150.35 acres. How much land has he left?

A. Reducing the fraction to a decimal and then uniting the numbers, we have

$$\begin{array}{r} 102.80 \\ 72.46 \\ 31.50 \\ \hline 206.76, \end{array}$$

which equals the number of acres purchased. From this deduct the 150.35, the number of acres sold, and the difference will be

$$\begin{array}{r} 206.76 \\ 150.35 \\ \hline 56.41, \end{array}$$ the number of acres remaining.

Multiplication of Fractions and Decimals.

Q. 25. How are fractions and decimals multiplied?

A. In the case of common fractions, when there are integers or

mixed numbers, reduce them to improper fractions; then multiply the numerators together for a new numerator, and denominators for a new denominator. Thus $\frac{8}{9}$ multiplied by $.7=\frac{8}{9}\times\frac{7}{10}=\frac{56}{90}=\frac{28}{45}$. In the case of decimals, place the factors under each other and multiply them together, as in whole numbers. Then from the right hand of the product point off as many figures for decimals as there are decimal places in both factors, and when there are not enough figures for this purpose, prefix enough ciphers to supply the deficiency. Thus 4.21 multiplied by .62 equals

$$\begin{array}{r} 4.21 \\ \underline{.62} \\ 842 \\ \underline{2526} \\ 2.6102 \end{array}$$

Division of Fractions and Decimals.

Q. 26. What rules can be given for the division of fractions and decimals?

A. In case of common fractions, reduce all integers and mixed numbers to improper fractions, and then invert the terms of the divisor and proceed as in multiplication of fractions. In case of decimals, divide as in whole numbers, and from the right hand of the quotient point off as many places for decimals as the decimal places in the dividend exceed those in the divisor.

Q. 27. If $\frac{3}{10}$ of a ton of coal is worth $\$1\frac{1}{6}$, what is a ton worth?

A. $1\frac{1}{6}$ when reduced to an improper fraction$=\frac{7}{6}$. Now, if $\frac{3}{10}$ of a ton of coal is worth $\frac{7}{6}$ dollars, one ton will be worth as many dollars as $\frac{3}{10}$ is contained in $\frac{7}{6}$, which by the rule is found by multiplying $\frac{7}{6}$ by $\frac{10}{3}=\frac{70}{18}$ dollars$=3\frac{8}{9}$ dollars$=\$3.88\frac{8}{9}$.

Q. 28. How many revolutions will a car wheel, 8.448 feet in circumference, make in traveling a distance of one mile, if nothing is lost through friction?

A. One mile=5,280 feet. This divided by the circumference of the wheel will determine the number of revolutions it makes. Thus

$$\begin{array}{l} 8.448)5,280.000(625,\ \text{answer.} \\ \qquad\quad \underline{5\ 068\ 8} \\ \qquad\qquad 211\ 20 \\ \qquad\qquad \underline{168\ 96} \\ \qquad\qquad\ \ 42\ 240 \\ \qquad\qquad\ \ \underline{42\ 240} \end{array}$$

LESSON III.

Percentage.

Q. 29. What is meant by the term per cent, and what are the modes of expressing it?

A. Per cent means by the hundred, and applies to any denomination whatever. Thus, 8 per cent means 8 parts in a hundred, and may refer as well to 8 bushels of coal in a hundred as to 8 dollars in a hundred. Per cent may be expressed equally well by the character %, by a common fraction, or by a decimal. Thus, 8 per cent = 8% = .08. In the solution of problems, however, it is customary to use the decimal form of expression.

Q. 30. In the study of percentage, what five elements are required, and what does each mean?

A. The rate, or rate per cent, is the number expressing how many hundredths of a given quantity are to be taken. The percentage is that part of the given quantity indicated by the rate. The base is the quantity itself on which the percentage is computed. The amount is the sum of the base and percentage taken together. The difference is the remainder after subtracting the percentage from the base.

Q. 31. When the base and rate are given, how can the percentage be found?

A. The percentage can be found by multiplying the base by the rate expressed as a decimal.

Q. 32. A mining company begins business with a bank account of $5,000. 20% of this is drawn for a certain investment, but only 15% was used, the balance being returned to the bank. What was the amount of deposit after this transaction?

A. 20% of $5,000 is 5,000 × .20 = 1,000, the number of dollars drawn from the bank. The amount remaining was, therefore, $4,000. As only 15% was used, 5% was returned to the bank. Thus 5,000 × .05 = 250, the number of dollars returned. The amount of the deposit at the end of this transaction was, therefore, $4,000 + $250 = $4,250.

Q. 33. When the base and percentage are given, how can the rate be found?

A. The rate can be found by dividing the percentage by the base, as in division of decimals.

Q. 34. In shipping a car load of 30 tons of coal from Iowa to South Dakota, 900 pounds were lost or stolen. What was the rate per cent of the shortage?

A. In 30 tons there were $30 \times 2{,}000$ pounds $=$ 60.000 pounds. The per cent of shortage is, by the rule, 900 divided by 60,000. Thus

60,000) 900.000 (.015 = 1½%, answer.
600 00
300 000
300 000

Q. 35. When the percentage and rate are given, how can the base be found?

A. The base can be found by dividing the percentage by the rate.

Q. 36. The actual horse power of a boiler is 120, which, owing to loss of steam, poor firing, friction, etc., is only 60% of its theoretical capacity. What is the theoretical horse power of the boiler?

A. The percentage here is 120 and the rate .60. Dividing the former by the latter we have

.60) 120.00 (200, answer.
120
00

The reason for this becomes clear when the problem is analyzed, for if sixty per cent of the theoretical horse power is 120, one per cent is 2 horse power, and one hundred per cent, or the total theoretical amount, is 100×2, which equals 200 horse power.

Q. 37. When the amount and rate are given, how can the base be found?

A. The base can be found by dividing the amount by 1 plus the rate.

Q. 38. A mercantile company in 1900 did a business amounting to $121,000, which was 10% greater than the business of 1899. What amount of business was done in 1899?

A. Applying the rule, we have

1.10) 121,000.00 (110,000 dollars, answer.
110
11 0
11 0
00 00

Q. 39. When the difference and rate are given, how can the base be found?

A. The base can be found by dividing the difference by 1 minus the rate.

Q. 40. Having sold 35% of my stock in a mining company, I still have 19,500 shares. How many shares did I own originally?

A. By dividing the 19,500 by 1 — .35, we have

```
.65 ) 19,500.00 ( 30,000, the original number of
      19 5                shares of my stock.
      -------
         00 00
```

Ratio and Proportion.

Q. 41. What is the meaning of simple ratio, and what sign is used to express it?

A. Ratio is the mathematical relation that one number bears to another number, and is expressed by two points (:). Thus 10 : 2 is read the ratio of 10 to 2. This may also be expressed $\frac{2}{10}$ and signifies that the ratio is one-fifth.

Q. 42. What is meant by a compound ratio?

A. A compound ratio is the product of two or more simple ratios. Thus from the two simple ratios, 5 : 15 and 2 : 7, we have

$$\begin{array}{r} 5 : 15 \\ \underline{2 : \;\;7} \end{array}$$

Then by multiplying, 10 : 105 is the compound ratio.

Q. 43. What is the ratio of $\frac{1}{6}$ to $\frac{8}{9}$?

A. This may be expressed $\frac{1}{6} : \frac{8}{9}$, and therefore becomes by division $\frac{8}{9} \times \frac{6}{1} = \frac{48}{9} = 5\frac{3}{9} = 5\frac{1}{3}$, answer.

Q. 44. What is meant by the term simple proportion, and what sign is used to express it?

A. Simple proportion is an equality of two simple ratios, and is expressed by four points (::). Thus 2 : 6 :: 3 : 9 is read the ratio of 2 to 6 is as the ratio of 3 to 9. Or, it may be expressed $\frac{6}{2} :: \frac{9}{3}$, the ratio in each case being 3.

Q. 45. What is meant by the terms cause and effect?

A. Anything that operates to produce a result may be regarded as a cause, while the change thus produced is known as the effect. As ordinarily used these terms are synonymous with antecedent and consequent.

Q. 46. What are the extremes, and what the means of a proportion?

A. The extremes of a proportion are the first and fourth terms, and the means the second and third terms. In all true proportions the product of the extremes is equal to the product of the means.

Q. 47. The ratio of 2 to 8 is as the ratio of 26 to what number?

A. As a proportion this may be stated 2 : 8 :: 26 : required number. Multiplying extremes and means, we have $8 \times 26 = 2 \times$ required number. The last term of the proportion is, therefore,

$$\frac{8 \times 26}{2} = 104, \text{ answer.}$$

Q. 48. What is a compound proportion?

A. A compound proportion is an equality between a simple and compound ratio, or between two compound ratios. Thus if

$$\begin{array}{l} 2:4 \;::6\; :12 \text{ and} \\ \underline{3:4 \;::6\; :\;\;8}\text{, then by multiplying similar} \end{array}$$

terms, we have $\quad 6:16::36:96.$

Q. 49. What rule can be given for stating a compound proportion?

A. Write all numbers constituting first cause in a vertical line as first term of the proportion, and all numbers constituting second cause in another vertical line as the second term of the proportion. Then for the first effect write in a vertical line all numbers constituting the third term of the proportion, and for the fourth term place all numbers constituting the second effect. The unknown number should be noted with an x. Multiply all numbers together in each vertical column for the new terms of a simple proportion, and then solve for the one that is unknown, designated by x.

Q. 50. If 8 men can mine 72 tons of coal in 3 days, how many tons of coal can 9 men mine in 4 days?

A. Putting this in the form of a proportion, we have

$$\begin{array}{l} 8 : 9 \;::\; 72 : x \\ \underline{3 : 4 \qquad\qquad\quad} \end{array}$$

Then $\quad 24 : 36 :: 72 : x.$

$$x = \frac{36 \times 72}{24} = 108, \text{ answer.}$$

Q. 51. If a block of granite 3 feet long, 2 feet wide and 1 foot thick weighs 970 pounds, what will a cube of the same material weigh that measures 2 feet on a side?

A. Stating this as a proportion, we have

$$\begin{array}{l} 3 \;\; 2 \\ 2 : 2 :: 970 : x \\ \underline{1 \;\; 2 \qquad\qquad\quad} \end{array}$$

Then $\quad 3 \times 2 \times 1 : 2 \times 2 \times 2 :: 970 : x$, or

$$6 : 8 :: 970 : x.$$

$$x = \frac{8 \times 970}{6} = 1{,}293\tfrac{1}{3}, \text{ the number of pounds, answer.}$$

LESSON IV.

Square and Cube Root.

Q. 52. What is meant by the power of a number?

A. The power of a number is the product arising from multiplying a number by itself one or more times. When the number is used twice as a factor, it is said to be squared, and when used three times as a factor, it is cubed. Thus the second power, or square, of 5 is 25, and is written 5^2. Likewise, the third power, or cube, of 8 is 512, and is written 8^3.

Q. 53. What is the square of 45?

A. 45 may be written $40 + 5$; hence, $45^2 = (40 + 5)^2$. This used twice as a factor gives

$$\begin{array}{r} 40 + 5 \\ 40 + 5 \\ \hline 40 \times 5 + 5^2 \\ 40^2 + 40 \times 5 \qquad \\ \hline 40^2 + 2\,(40 \times 5\,) + 5^2 \end{array}$$

This is equal to the square of the tens, plus twice the product of the tens and units, plus the square of the units.

Q. 54. What is the cube of 62?

A. 62 may be written $60 + 2$; hence $62^3 = (\,60 + 2\,)^3$. This used three times as a factor gives

$$\begin{array}{r} 60 + 2 \\ 60 + 2 \\ \hline 60 \times 2 + 2^2 \\ 60^2 + 60 \times 2 \qquad \\ \hline 60^2 + 2\,(60 \times 2) + 2^2 \\ 60 + 2 \\ \hline 60^2 \times 2 + 2\,(\,60 \times 2^2) + 2^3 \\ 60^3 + 2\,(60^2 \times 2) + \quad 60 \times 2^2 \qquad \\ \hline 60^3 + 3\,(\,60^2 \times 2\,) + 3\,(\,60 \times 2^2\,) + 2^3 \end{array}$$

This is equal to the cube of the tens, plus three times the square of the tens multiplied by the

units, plus three times the tens multiplied by the square of the units, plus the cube of the units.

Q. 55. What is meant by the root of a number?

A. The root of a number is one of the equal factors which produces it. Thus the square root of 49 is 7, because $7 \times 7 = 49$. So, also, the cube root of 216 is 6, because $6 \times 6 \times 6 = 216$. From the above facts it can be seen that the determination of power and root of a number is a converse process; and the principles used in determining the root of a number are derived from the process by which powers are obtained. It is also observed from these illustrations taht in the square root of a number there are one-half as many figures as are contained in the number itself, while in cube root there are one-third as many figures. Hence, in extracting square root the number should be separated into periods of two figures each, while in extracting cube root the number should be separated into periods of three figures each.

Q. 56. What is the square root of 6,241?

A.

	62 41 (79
7^2..................................	49
	13 41
$2(70 \times 9) + 9^2$....................	13 41

Since the number contains four figures, it is separated into two periods, and the square root will contain two figures, tens and units. The greatest square that 62 contains is 49, which has a root of 7. This figure is placed to the right of the number and represents the tens term of the root. Subtracting the 49 from 62, leaves a remainder of 13, to which is annexed the 41, making 1,341. According to the answer of question 54, this remainder is composed of twice the product of the tens and units of the root, plus the square of the units. The first figure of the root considered as tens equals 70, and twice this is 140, which gives an approximate divisor for determining the units figure of the root. This 140 is contained in 1,341 9 times, which is the units of the root. Twice the tens multiplied by the units, plus the square of the units, is placed to the left and equals 1,341, which is the partial number whose root is extracted. Thus 79 is the square root of 6,241. Proof: $79 \times 79 = 6{,}241$.

Q. **57.** What is the square root of 31.5844?

	31.58 44 (5.62
5^2..............................	25
	6 58
$2\,(50 \times 6) + 6^2$..................	6 36
	22 44
$2\,(560 \times 2) + 2^2$..................	22 44

From the decimal point separate into periods of two figures each, and it is seen that the root will contain, beside the whole number, a decimal of two figures. The largest square contained in 31 is 25, and the root of this is 5, which is placed to the right. This, considered as tens and then doubled, equals 100. This gives 6 as the units figure of the root. Now, twice the tens multiplied by the units, plus the square of the units is 636, which, subtracted from 658, leaves a remainder of 22. To this annex the last two figures of the number and we have 2,244. Considering 56 now as the tens, and doubling it, gives 1,120. This goes into 2,244 twice for the units figure of the root. Then twice the tens multiplied by the units, plus the square of the units, is set to the left and equals 2,244. This, when subtracted from the partial number whose root is extracted, leaves no remainder. Thus 5.62 is the square root of 31.5844. Proof: $5.62 \times 5.62 = 31.5844$.

Q. 58. What is the cube root of 117,649?

A.

	117 649 (49
4^3.................................	64
	53 649
$3\,(40^2 \times 9) + 3\,(40 \times 9^2) + 9^3$......	53 649

Separate the number into periods of three figures each. The largest cube contained in the left hand period is 64, the root of which is 4. 64 subtracted from 117 leaves 53, to which is annexed the balance of the number, making 53,649. According to the answer of question 55, this consists of three times the square of the tens multiplied by the units, plus three times the tens multiplied by the square of the units, plus the cube of the units. Now, considering the 40 as tens, its square multiplied by 3 and used as an approximate divisor gives 9 as the units figure of the root. Completing the cube by using these values for the tens and units, we have three times the square of 40 multiplied

by 9, plus 3 times 40 multiplied by 9 square, plus 9 cubed equal to 53,649. This is the same as the partial number remaining whose root was sought. Hence the cube root of 117,649 is 49. Proof: $49 \times 49 \times 49 = 117,649$.

Q. 59. What is the cube root of 44.361864?

A.

	44.361 864 (3.54
3^3	27
	17 361
$3(30^2 \times 5) + 3(30 \times 5^2) + 5^3$....	15 875
	1 486 864
$3(350^2 \times 4) + 3(350 \times 4^2) + 4^3$....	1 486 864

Beginning with the decimal point, separate the number into periods of three figures each. The cube root will contain one figure in the whole number and two figures in the decimals. The greatest cube that is contained in 44 is 27. The cube root of this is 3, which is placed to the right with a decimal point following it. 27 subtracted from 44 leaves a difference of 17, to which is annexed the first period of decimals, making 17,361. This is composed of three times the square of the tens multiplied by the units, plus three times the tens multiplied by the square of the units, plus the cube of the units. By trial, it is found that three times the square of the tens, when used as a divisor, gives 5 as the next figure of the root. Then completing the approximate correction, we have three times the square of 30 multiplied by 5, plus three times 30 multiplied by 5 square, plus 5 cubed equal to 15,875. Taking this from 17,361, leaves 1,486, to which is annexed the remainder of the number, making 1,486,864. This again is composed of three times the tens squared multiplied by the units, plus three times the tens multiplied by the units squared, plus the units cubed. Considering the 35 as tens, its square multiplied by three gives an approximate divisor of 367,500, which shows that the last figure of the root is 4. Proceeding now with this, as in the previous case, we have for the completed number whose cube root is sought, three times 350 squared multiplied by 4, plus three times 350 multiplied by 4 squared, plus 4 cubed, which makes 1,486,864. This is the same as the remainder, and therefore completes the cube. Hence the cube root of 44.361864 is 3.54. Proof: $3.54 \times 3.54 \times 3.54 = 44.361864$.

CHAPTER II.—MENSURATION.

LESSON V.

Definitions.

Q. 60. What is meant by the term mensuration?

A. Mensuration is that part of applied geometry which gives the rules for determining the length of lines, the area of surfaces and the volume of solids.

Q. 61. What is an angle? What a right angle? What an acute angle? What an obtuse angle?

A. An angle is the inclination made by one line with another. A right angle is formed by two lines that are perpendicular, and is equal to 90°. An acute angle is less than a right angle, while an obtuse angle is greater than a right angle.

Q. 62. What is a plane triangle? What are some of the plane triangles called?

A. A plane triangle is a figure bounded by three straight lines, and receives different names according to the nature of its sides and angles. Thus an equilateral triangle has all its sides equal; an isosceles triangle has only two of its sides equal; a scalene triangle has all of its sides unequal; a right angle triangle has a right angle. The side opposite the right angle in this triangle is called the hypothenuse, while the other two sides are called the base and perpendicular. In any plane triangle the sum of the three angles is equal to two right angles.

Q. 63. What are some of the plane geometrical figures bounded by four lines?

A. A quadrilateral is any figure bounded by four straight lines. A square is a quadrilateral whose sides are all equal and whose angles are all right angles. When the adjacent sides of a quadrilateral are unequal, but all the angles right angles, the figure is called a rectangle. A rhombus is a quadrilateral whose sides are all equal, but its angles not right angles. A parallelogram is a quadrilateral whose opposite sides are parallel, and if the angles are not right angles and adjacent sides unequal it is called a rhom-

boid. A trapezoid is a quadrilateral having two of its opposite sides parallel, while a trapezium is a quadrilateral having no two sides parallel.

Q. 64. What are the principal geometrical solids bounded by plane or curvilinear surfaces?

A. A cube is a solid contained by six equal, square sides or faces. A parallelopipedon is a solid contained by six rectangular plane faces, the opposite ones being equal and parallel. A prism is a solid whose ends are two equal, parallel and similar plane figures, and its sides parallelograms. A cylinder is a solid of roller-like form whose longitudinal section is a parallelogram and cross section a circle. A sphere is a solid described by the revolution of a semicircle about its diameter.

Mensuration of Lines.

Q. 65. What is the relation of the sides of similar geometrical figures?

A. The sides of similar geometrical figures are proportional to each other.

Q. 66. The base and perpendicular of a rectangle are 12 and 10 feet respectively. What is the base of another similar rectangle, if its perpendicular is 8 feet?

A. Let x equal the required base. Then as the sides are proportional, 12 : 10 :: x : 8. Or $x = \frac{12 \times 8}{10} = 9.6$ feet, the length of the base.

Q. 67. The base of a triangle is 15 inches and one of the other sides is 10 inches. What is the corresponding side of a similar triangle whose base is 30 inches?

A. Let x equal the required side. Then 15 : 30 :: 10 : x. Or $x = \frac{30 \times 10}{15} = 20$, the number of inches in the corresponding side of the similar triangle.

Q. 68. What is the relation of the hypothenuse of a plane right angle triangle to its other two sides?

A. The square of the hypothenuse of any plane right angle triangle is equal to the sum of the squares of the other two sides.

Q. 69. Two ships sail from the same port. In a certain length of time one ship has gone due north 60 miles, and the other ship has

gone due east 80 miles. What is the distance between them?

A. These distances may be regarded as the shorter sides of a right angle triangle. The hypothenuse is found by extracting the square root of the sum of the squares of these two sides. Thus $60^2+80^2=3,600+6,400=10,000$. The square root of this is

	1 00 00(100
1^2................	1
	00 00

Hence the distance between the ships is 100 miles.

Q. 70. A ladder 30 feet in length is placed against a house in such a manner as to reach 24 feet from the ground. How far is the base of the ladder from the building?

A. The ladder forms with the house a right angle triangle in which the hypothenuse is 30 feet and the perpendicular 24 feet. The base is found by extracting the square root of the difference of the squares of these numbers. Thus $30^2-24^2=900-576=324$. The square root of this is

	3 24(18
1^2..................	1
	2 24
$2(10\times 8)+8^2$.........	2 24

Hence 18 feet is the distance from the base of the ladder to the house.

Q. 71. What is the relation of the circumference of a circle to its diameter?

A. The circumference of a circle is equal to 3.1416 multiplied by its diameter. This relation should be remembered, as it is used frequently in mathematical work.

Q. 72. What is the circumference of the earth, considering that its diameter is 7,935 miles?

A. The circumference of the earth equals $3.1416\times 7,935=24,928.596$ miles.

Q. 73. If the circumference of a fly wheel of an engine is 16 feet and 6 inches, what is its diameter?

A. 16 feet and 6 inches = 16.5 feet. Then $16.5\div 3.1416=5.252+$, the number of feet in the diameter of the wheel.

Mensuration of Surfaces.

Q. 74. How is the area of a square determined?

A. The area of a square is found by multiplying one of its sides by itself.

Q. 75. What is the area of a mining shaft 6 feet square?

A. $6 \times 6 = 36$, the number of square feet in the cross section of the shaft.

Q. 76. The area of a square is 2,025 square feet. What are the dimensions of its sides?

A. Since the area of a square is found by multiplying a side by itself, it follows that a side of a square is found by extracting the square root of its area Thus the square root of 2,025 is

	20 25(45
4^2	16
	4 25
$2(40 \times 5) + 5^2$..........	4 25

Hence a side of the square is 45 feet

Q. 77. How is the **area** of a rectangle determined?

A. The area of a rectangle is found by multiplying its length by its breadth.

Q. 78. How many square feet are contained in 20 boards, each 18 feet long by 18 inches wide?

A. 18 inches $= 1.5$ feet. Then each board has an area of $18 \times 1.5 = 27$ square feet, and 20 boards have 20 times this area, which is 540 square feet.

Q. 79. The length of a rectangular room is 22 feet, and its area is 396 square feet. What is its width?

A. Since the area of a rectangle is determined by multiplying its length by its width, it follows that the area divided by one of its sides gives the magnitude of the other side. Hence $396 \div 22 = 18$, the number of feet in the width of the room.

Q. 80. What is the rule for determining the area of a rhombus and rhomboid?

A. The area of a rhombus and rhomboid is equal to the product of the base and altitude.

Q. 81. What is the area of a rhombus whose base is 32 feet, and altitude 12 feet and 3 inches?

A. 12 feet and 3 inches $= 12.25$ feet. Then $32 \times 12.25 = 392$, the number of square feet in its area.

Q. 82. The base of a rhomboid is 20 feet and 6 inches, and its area 369 square feet. What is its altitude?

A. 20 feet and 6 inches $= 20.5$ feet. Then $369 \div 20.5 = 18$, the number of feet in the altitude of the rhomboid.

LESSON VI.

Q. 83. How is the area of a triangle determined?

A. The area of a triangle is equal to one-half the product of its base and altitude.

Q. 84. What is the area of a scalene triangle whose base is 20 feet and altitude 12 feet and 9 inches?

A. 12 feet and 9 inches = 12.75 feet. Hence the area of the triangle $= \dfrac{20 \times 12.75}{2} = 127.5$ square feet.

Q. 85. The base of an isosceles triangle is 12 feet, and its area 48 square feet. What are the other two sides of the triangle?

A. The area divided by the base gives one-half the perpendicular. Thus $48 \div 12 = 4$. Hence the perpendicular is 8 feet. This perpendicular divides the base into two equal parts, each of which is 6 feet. Then we have the base 6 and perpendicular 8 of a right angle triangle to find the hypothenuse. This is done by extracting the square root of the sum of the squares of the two shorter sides. Thus $6^2 + 8^2 = 36 + 64 = 100$. The square root of this is 10. Hence each of the two equal sides of the isosceles triangle is 10 feet.

Q. 86. How is the area of a trapezoid determined?

A. The area of a trapezoid is found by multiplying one-half the sum of the two parallel sides by the perpendicular distance between them.

Q. 87. What is the area of a trapezoid whose two parallel sides are 12 and 16 feet respectively, and whose altitude is 6 feet?

A. One-half the sum of the two parallel sides is $\dfrac{12 + 16}{2} = 14$ feet. $14 \times 6 = 84$, the number of square feet in the trapezoid.

Q. 88. How is the area of a trapezium determined?

A. The area of a trapezium is equal to one-half the product of the diagonal and the sum of the two perpendiculars upon it from the opposite angles of the trapezium.

Q. 89. What is the area of a trapezium whose diagonal is 32 inches, when the perpendiculars upon it are 12 and 16 inches respectively?

A. The area of the trapezium is $\frac{12 + 16}{2} \times 32 = 448$ square inches.

Q. 90. How is the lateral surface of a parallelopipedon determined?

A. The lateral surface of a parallelopipedon is found by adding the surface of its several lateral faces.

Q. 91. What is the rubbing surface of an airway 3,000 feet long, when its cross section is 7 by 9 feet?

A. Two of the faces are 7 by 3,000 square feet, and the other two are 9 by 3,000 square feet. Hence the total rubbing surface is $7 \times 3{,}000 + 7 \times 3{,}000 + 9 \times 3{,}000 + 9 \times 3{,}000 = 96{,}000$ square feet.

Q. 92. What is the relation of the radius of a circle to its area?

A. The area of a circle is equal to 3.1416 multiplied by the square of its radius. It is also equal to .7854 multiplied by the square of its diameter.

Q. 93. What is the area of a piston head whose diameter is 18 inches?

A. The square of the radius of the piston head = 81. Then $81 \times 3.1416 = 254.469+$ square inches.

Q. 94. What is the diameter of a circle whose area is 23.562 square feet?

A. By dividing the area of the circle by .7854 we get the square of the diameter. Thus $23.562 \div .7854 = 30$. The square root of this equals 5.477+, which is the number of feet in the diameter of the circle.

Q. 95. How is the surface of a sphere determined?

A. The surface of a sphere is equal to 3.1416 multiplied by the square of its diameter.

Q. 96. What is the surface of a globe having a diameter of 12 feet?

A. $12^2 = 144$. Then $3.1416 \times 144 = 452.390$ square feet, the surface of the globe.

Q. 97. What is the relation of the area of similar geometrical figures?

A. The areas of similar geometrical figures are to each other as the square of their corresponding sides.

Q. 98. The base of a triangle is 12 feet, and its area is 4 square feet. What is the area of a similar triangle having a base of 10 feet?

A. The areas of these triangles are as 12^2 to 10^2. Let x equal the area of the triangle whose base is 10 feet. Then 44 : x :: 144 : 100.

$$\text{Or } x = \frac{44 \times 100}{144} = 30\tfrac{5}{9} \text{ square feet in the similar triangle.}$$

Q, 99. Two similar geometrical figures have areas of 144 and 256 square feet respectively. What is the relation of their corresponding sides?

A. Since the areas of similar geometrical figures are to each other as the square of their corresponding sides, it follows that the sides of such figures are to each other as the square root of their areas. Hence the relation of the corresponding sides of these figures is as the square root of 144 to the square root of 256, which is as 12 to 16. Therefore the similar sides of these figures bear the relation of 12 to 16.

Mensuration of Solids.

Q. 100. How is the volume of a cube determined?

A. The volume of a cube is equal to the cube of one of its sides.

Q. 101. How many cubic inches are contained in a cube of masonry 2 feet on a side?

A. 2 feet = 24 inches, and 24 inches cubed equals $24 \times 24 \times 24 = 13{,}824$ cubic inches, which is the volume of the block of masonry.

Q. 102. What are the dimensions of a cube whose volume is 1,331 cubic inches?

A. As the volume of a cube is determined by cubing one of its sides, so one of the sides of a cube is determined by extracting the cube root of its volume. The cube root of 1,331 is

$$\begin{array}{ll} & 1\,331(11 \\ 1^3 \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots & \underline{1} \\ & 331 \\ 3\,(10^2 \times 1) + 3\,(10 \times 1^2) + 1^3 \ldots & \underline{331} \end{array}$$

Hence 11 inches is the side of a cube whose volume is 1,331 cubic inches.

Q. 103. How is the volume of a parallelopipedon measured?

A. The volume of a parallelopipedon is measured by multiplying its length, breadth and thickness together.

Q. 104. The length of a parallelopipedon is 36 inches, its width is 20 inches and its depth is 18 inches. How many cubic feet does it contain?

A. Its volume equals $36 \times 20 \times 18 = 12{,}960$ cubic inches. But, as a cubic foot contains 1,728 cubic inches, there are as many cubic feet in the parallelopipedon as 1,728 is contained in 12,960, which is 7.5.

Q. 105. How is the volume of a prism determined?

A. The volume of a prism is equal to the area of its base multiplied by its altitude.

Q. 106. The end of a triangular prism has an area of 320 square inches, and its altitude is 42 inches. What is its volume?

A. The volume of the prism is $320 \times 42 = 13{,}440$ cubic inches.

Q. 107. How is the volume of a cylinder determined?

A. The volume of a cylinder is equal to the area of its base multiplied by its altitude.

Q. 108. The length of a cylinder is 20 feet and its diameter is 24 inches. What is its volume?

A. 24 inches = 2 feet. The area of the base of the cylinder is, therefore, 3.1416 square feet. Hence the volume of the cylinder is $20 \times 3.1416 = 62.832$ cubic feet.

Q. 109. The diameter of the base of a cylinder is 20 inches and its volume is 9,424.8 cubic inches. What is its altitude?

A. The base of the cylinder is $.7854 \times 20 \times 20 = 314.16$ square inches. This divided into the volume gives the altitude. Thus $9{,}424.8 \div 314.16 = 30$, the number of inches in the altitude of the cylinder.

Q. 110. How is the volume of a sphere measured?

A. The volume of a sphere is equal to one-sixth of the cube of its diameter multiplied by 3.1416.

Q. 111. What is the volume of a globe whose diameter is 12 inches?

A. The volume of this sphere is $\dfrac{12^3 \times 3.1416}{6} = 904.780$ cubic inches.

Q. 112. What is the relation of the volumes of similar solids?

A. The volumes of similar solids are to each other as the cubes of their like dimensions.

Q. 113. What are the relative volumes of two spheres whose respective diameters are 5 and 8 inches?

A. $5^3 = 125$ and $8^3 = 512$. Then the volumes of the two spheres are as 125 to 512.

CHAPTER III.—MECHANICS.

LESSON VII.

Definitions and Elementary Principles.

Q. 114. What is meant by the term mechanics?

A. Mechanics is that branch of physical science which treats of the equilibrium and motion of bodies.

Q. 115. What is the nature of the material that composes all bodies?

A. All bodies are composed of matter. This may be defined as anything which may be detected by the senses, or is capable of occupying space. All forms of matter consist of molecules and atoms.

Q. 116. What are molecules? What are atoms?

A. A molecule is the smallest particle of any substance that can exist in the free state. This is a unit much smaller than any mechanical subdivision of matter. If a molecule is divided, it separates into atoms. These atoms are the smallest particles of matter that are capable of entering into or existing in a chemical combination. No process can separate atoms into anything more elementary, and when matter is composed only of one kind of atoms, it represents the elements that compose all bodies. Atoms unite to form molecules, and an aggregation of molecules forms the mass of all bodies of matter.

Q. 117. What is there that holds matter in a condition of equilibrium or gives it motion?

A. Anything which tends to give equilibrium or motion to a body is called force. A force may hold a body at rest or it may increase or decrease its motion. If it acts between adjacent particles, it is called a molecular force, but if it is applied from without, it is called an extraneous force. Most of the forces dealt with in mechanics are extraneous, and manifest themselves as attractive or repulsive according to their nature.

Q. 118. In studying the effect of a force on a body, what conditions must be fulfilled?

A. That the effect of a force on a body may be ascertained it is necessary to know the point of application, the direction and the magnitude of the force. The direction of a force is generally indicated by a straight line, while the unit of magnitude of a force for mechanical purposes is taken as the pound, which is a unit of weight.

Q. 119. What is gravity, and what are the laws of universal gravitation?

A. Gravity is the attraction between the earth and all bodies on or near its surface. It is the force that measures the weight of a body, which is the result of attraction upon all its particles. But the weight of a body varies according to its distance from the center of the earth, and it weighs more at the surface of the earth than below or above it. Within the circumference of the earth, the force of gravity is partly overcome by the forces surrounding it, and the weight of a body decreases directly as the distance to the center diminishes. But outside the earth, the force of attraction is supposed to extend throughout all space and is known as universal gravitation. The intensity of this force outside the earth varies directly as the product of the masses of the attracting bodies, and inversely as the square of the distance between them.

Q. 120. If a body weighs 200 pounds at the surface of the earth, what would be its weight one-half way to the earth's center?

A. Within the earth the weight of a body varies directly as its distance from the center. Hence if a body weighs 200 pounds at the surface of the earth it would weigh one-half of 200 pounds, or 100 pounds, if taken half-way to the earth's center.

Q. 121. If a body weighs 200 pounds on the surface of the earth, what would it weigh at an elevation of 3,967.5 miles above the surface?

A. The earth's radius is about 3,967.5 miles, and the same distance above the surface is 7,935 miles from its center of attraction. The weight of the body at this point, represented by x, is to its weight on the surface as $3{,}967.5^2 : 7{,}935^2$. Or, $x : 200 :: 1^2 : 2^2$.

Hence $x = \dfrac{200 \times 1}{4} = 50$ pounds.

Q. 122. What is meant by the specific gravity of a body?

A. The specific gravity of a body is the ratio of the weight of a given volume of that body to the weight of an equal volume of pure water, which is taken as the unit of specific gravity. A body that is twice as heavy as water for the same volume is said to have a specific gravity of 2.

Q. 123. A cubic foot of distilled water weighs 62.5 pounds. If a cubic foot of bituminous coal weighs 78.125 pounds, what is its specific gravity?

A. The specific gravity of the coal, according to the definition of specific gravity, is $\frac{78.125}{62.5} = 1.25$, answer.

Q. 124. What is meant by center of gravity, and how can it be determined by the moment of forces?

A. Center of gravity is a point about which all the matter comprising a body can be balanced or may be considered as concentrated. It is the point at which forces are applied in estimating their influence in creating stability or producing motion. In all conditions of equilibrium, the forces that tend to create motion are overcome by those of resistance. But whenever they are applied at points away from their centers of attraction they have a turning power. This power which tends to swing a body around its point of support is called the moment of the force, and is equal to the magnitude of the force multiplied by the length of the perpendicular line between its direction and the turning point. Thus, if a force of 10 pounds acts at right angles on an arm 3 feet in length, the moment of that force is $10 \times 3 = 30$ units. When a body is in equilibrium, the moment of any turning force is overcome by the moments of other forces acting in the opposite direction.

Q. 125. Two bodies held rigidly apart at a distance of 110 inches weigh 50 and 60 pounds respectively. At what point between them can their weight be balanced by a single force?

A. The point of application of the balancing force is the center of gravity of the two weights, which will be on the line joining their centers of gravity. Suppose its distance from the center of gravity

of the 50-pound weight is called x, then its distance from the center of gravity of the 60-pound weight is 110—x. As this point is one of equilibrium, the moments of the forces acting on each side of it are equal. Hence $50x = 60 \ (110-x) = 6{,}600 - 60x$. Hence $110x = 6{,}600$, or $x = 60$. The point of application of the force is, therefore, 60 inches from the center of gravity of the 50-pound weight.

Q. 126. What is meant by the terms motion and velocity?

A. Motion means change of position in relation to some fixed point. When a bullet is projected from a rifle, and a train moves from one place to another, they are said to have motion. Velocity is the rate of motion, and is measured by the distance the body passes over in a unit of time. When motion is given to a body by a single force acting only for an instant, the body passes over equal distances in the same time, and the velocity is uniform. But if the propelling force is constant and continues to act upon the body after motion begins, the velocity increases in direct proportion to the time it acts, and is called uniformly accelerated velocity. The force of gravity is constant and the velocity it imparts to falling bodies is uniformly accelerated.

Q. 127. What is meant by the mass of a body? What by momentum?

A. The mass of a body is the quantity of matter which it contains. If the force of gravity were the same everywhere, the weight of a body might be taken as a measure of its mass, but gravity varies in the same ratio as weight varies, while the mass remains constant. So, if we denote the weight of any body by w, its mass by m, and the force of gravity at that place by g, then we have the relation $w = mg$. For ordinary purposes the unit of mass is taken as the pound; so the terms weight and mass may be regarded as synonymous for any one place. The momentum of a body is its quantity of motion. It is the result obtained by multiplying its mass by the velocity. When acting upon bodies free to move, equal forces produce equal momenta, or quantities of motion. Hence the resultant action of a force applied to a body may be represented by $f = mv$, in which f is the force, and mv its momentum.

LESSON VIII.

Q. 128. What is the relation between space and time for a body moving with a uniform velocity?

A. For a body moving with a uniform velocity the space passed over is equal to the velocity multiplied by the time during which the body moves. Thus $s = vt$, in which s represents space, v velocity and t time.

Q. 129. If a railway train moves with an average velocity of 22 miles an hour for 3.2 hours, how far does it go?

A. Using the formula $s = vt$, we have $s = 22 \times 3.2 = 70.4$ miles. Or, by analysis we may say that if the train moves 22 miles in 1 hour, in 3.2 hours it will move 3.2 times 22 miles, which is 70.4 miles.

Q. 130. What is the acceleration in velocity of falling bodies?

A. Experiments show that a body falling freely from a state of rest acquires at the end of one second a velocity of 32.16 feet. Since the force of gravity, which is constant, produces this acceleration, the body will make a like gain in velocity during each succeeding second of time it continues to fall. This increment in velocity is commonly called acceleration of gravity, and the velocity the body acquires at any time may be represented by the formula $v = gt$, in which v represents the velocity at the end of any second, g the acceleration of gravity, and t the number of seconds during which the body is falling. That is, the velocity of a freely falling body at the end of any second of its descent is equal to 32.16 feet multiplied by the number of seconds. With ascending bodies we have the direct opposite of falling ones. When they drop, gravity increases their velocity each second by the quantity g, but when they are projected upward, gravity diminishes their velocity by the same amount. So the initial velocity that must be given a body to rise for any number of seconds is the same as the final velocity of a body that has been falling for the same number of seconds.

Q. 131. Through what distance will a freely falling body descend in a given time?

A. As the velocity increases in a constant ratio from a state of rest, the average velocity is one-half its final amount, or $\frac{1}{2}$ v. The space it passes over in t seconds of time will, therefore, be $s = \frac{1}{2} vt$. By substituting the value, $v = gt$, in this equation, we have $s = \frac{1}{2} gt^2$, an expression that shows the relation between space and time for falling bodies. Hence the distance that an unimpeded body will fall in a given time is equal to 16.08 feet ($\frac{1}{2}$ g) multiplied by the square of the number of seconds it is falling. If the body be projected vertically upward, it will lose 32.16 feet of its velocity each second until it comes to rest, and will rise a distance equal to 16.08 feet multiplied by the square of the number of seconds it is ascending.

Q. 132. A body drops from a high elevation. How far will it fall in three seconds, if there is no resistance?

A. Substituting the value of g, which is 32.16 feet, and t, which is 3 seconds, in the formula $s = \frac{1}{2} gt^2$, we have $s = 16.08 \times 3^2 = 144.72$ feet, the distance the body will fall in three seconds.

Q. 133. When a ball is projected vertically upward with a velocity of 321.6 feet per second, how high will it rise?

A. By substituting the value of v, which is 321.6 feet, in the formula $v = gt$, we have $321.6 = 32.16$ t, from which t is found to be 10 seconds. Now, substituting the value of g, and this value of t, in the formula $s = \frac{1}{2} gt^2$, we have $s = 16.08 \times 10^2 = 1608$ feet, the height to which the ball will rise.

Q. 134. What is meant by the term energy? What by work?

A. Energy is the power of doing work, or ability to overcome resistance. Work depends upon motion and involves two factors, force and distance through which the force acts, but it is independent of time. A force that is applied to a body without producing motion does no work, because no change of position is implied. The product of the force and distance through which the body is moved by the force is a measure of the work done.

Q. 135. What is the mechanical unit of work? What is meant by the term horse-power?

A. The unit of work most commonly used is the foot-pound, which

is the amount of work required to raise one pound of matter one foot high against the force of gravity. Rate of doing work is called power, and a horse-power represents the ability to perform 33,000 foot-pounds of work in one minute. To compute the amount of work done by any moving force, multiply the number of pounds raised by that force by the number of feet through which it acts, and divide the product by 33,000. The result will be the horse-power.

Q. 136. What is the horse-power of an engine that will raise 1,500 pounds 4,752 feet in 6 minutes?

A. 1,500 pounds raised 4,752 feet in 6 minutes $= \frac{1,500 \times 4,752}{6}$ pounds in one minute $= 1,188,000$ foot-pounds of work. Now, as a horse-power is 33,000 foot-pounds of work per minute, the engine has as many horse-power as 33,000 is contained in 1,188,000, which is 36.

Q. 137. What is meant by potential energy? What by kinetic energy? What is the relation of these two forms of energy?

A. Potential energy is energy of position, while kinetic energy is energy of motion. When a body is raised against gravity to an elevation, it has stored in it energy by virtue of its position, and an equivalent in energy of motion must be expended. But in dealing with gravity, we have already found that $v = gt$, or $t = \frac{v}{g}$. Hence $t^2 = \frac{v^2}{g^2}$. So also $s = \frac{1}{2} gt^2$. By substituting the value of t^2, in this expression, from the former equation, we have $s = \frac{v^2}{2g}$. Multiplying both sides of this expression by w, then $ws = \frac{wv^2}{2g}$. Or, since $w = mg$, as shown in answer to question 127, $ws = \frac{1}{2} mv^2$. The left-hand side of this equation represents work done against gravity in altering the position of the body, for to raise w pounds of matter through the space s requires ws foot-pounds of work, which is an expression of potential energy. The right-hand side of the equa-

tion represents the ability of the body due to its motion to overcome resistance, which is a measure of its kinetic energy.

Elementary Machines.

Q. 138. What is a machine?

A. A machine is a mechanical appliance in which a force applied at one point is made to produce an effect at some other point. All machines consist of simple parts, like the lever, wheel and axle, pulley, inclined plane, wedge and screw, and the laws governing complicated machinery depend upon the principles which control the elementary parts. No machine, whether elementary or compound, can create energy or do work of its own accord. In fact, every machine wastes energy in overcoming the resistance of its friction. The beneficial work which it can do is always less than the energy given into it by the amount of work required to overcome its friction.

Q. 139. What is a lever? What are the different classes of levers? What principle governs their action?

A. A lever is a rigid bar capable of being turned about a fixed point called its fulcrum, and acted upon by a force and a weight in a plane at right angles to its axis. There are three classes of levers, depending upon the position of the power, weight and fulcrum. In the first class, the fulcrum is between the power and the weight, as in the case of a crowbar, balance and shears. In the second class the weight is between the power and the fulcrum, as in the case of a cork-squeezer, nut-cracker and wheel-barrow. In the third class the power is between the weight and the fulcrum, as in the case of a pair of tongs, sheep-shears and the human arm. All classes of levers when in equilibrium are governed by the principle of movements, which is that the power multiplied by the perpendicular distance between its line of action and the fulcrum is equal to the weight multiplied by the perpendicular distance between its line of action and the fulcrum. If p represents a force with a lever arm c, and w a weight with a lever arm h, then when there is equilibrium $p c = w h$, or $p : w : : h : c$. Hence a force and weight acting on the arms of a lever in equilibrium are inversely proportional to the length of the lever arms.

LESSON IX.

Q. 140. If 20 pounds are applied at the end of an arm 40 inches long, acting as a lever of the second class, how much will this lift when the weight arm is 10 inches long?

A. Let the weight be represented by x. Then by the principle of moments, $10\,x = 20 \times 40 = 800$, or $x = 80$ pounds, answer.

Q. 141. What are compound levers, and what advantages arise from their use?

A. Compound levers consist of a combination of simple levers, so connected that the point of application of the weight of one constitutes the point of application of the power of the next, etc. These levers find their most important application in the construction of scales used for weighing railway cars, and heavy merchandise, like hay and coal. When such scales are constructed perfectly they are capable of weighing heavy articles to any desirable degree of accuracy. A system of compound levers that is in static equilibrium gives a final mechanical advantage that is equal to the product of the several values for each successive lever. Or, the power multiplied by the continued product of the several power lever arms is equal to the weight multiplied by the continued product of the several weight lever arms. Hence the power is to the weight as the continued product of the several weight lever arms is to the continued product of the several power lever arms.

Q. 142. What is a wheel and axle, and what law governs it?

A. A wheel and axle in its simplest form consists of two cylinders of different sizes, rigidly connected and turning about a common axis in such a manner that the larger one may be considered a wheel and the smaller one its axle. This is used to transmit power in the same manner as a lever of the first class, in which the power is applied tangentially at the circumference of the wheel, while the weight acts in the same manner from the circumference of the axle. In one of the most common forms, the power is applied by means of a

rope wound around the circumference of the wheel, while the weight is raised or lowered by another rope wound around the axle. In all such cases, the power arm is the radius of the wheel, while the weight arm is the radius of the axle. When the wheel and axle is in equilibrium, the moment of the power about the wheel is equal to the moment of the weight about the axle. If p represents the power acting on a wheel whose radius is c, and w the weight acting on an axle whose radius is h, then $pc = wh$, or $p : w :: h : c$. Hence if a power and weight acting on a wheel and axle are in equilibrium, the power is to the weight as the radius of the axle is to the radius of the wheel.

Q. 143. If a power of 80 pounds, acting on a wheel whose radius is 30 inches, balances a weight of 240 pounds suspended from the circumference of its axle, what is the radius of the axle?

A. Let the radius of the axle be represented by x. Now, since the power and weight are in equilibrium, $80 : 240 :: x : 30$. Then, $240x = 80 \times 30 = 2,400$, or $x = 10$ inches, the radius of the axle.

Q. 144. What is a pulley? What advantages are gained by its use? What law governs it?

A. A pulley is a wheel turning upon its axis and having a cord or belt passing over its circumference. When the pulley is fixed there is no increase of power, but there may be an advantage by change in the direction of the force. But when the pulley is movable, or when there are several pulleys in a movable block, the weight is sustained equally by all the parts of the cord supporting it, and there is a corresponding mechanical advantage. When one end of the cord is attached to the fixed pulley, the number of parts of the cord supporting the weight is twice the number of movable pulleys used, and when the fixed end of the cord is attached to the movable block, the number of parts of the cord is one more than twice the number of movable pulleys used. Hence the power is to the weight in a system of movable pulleys in equilibrium as 1 is to the number of parts of the cord supporting the movable block.

Q. 145. In a tackle having two blocks, each containing three pulleys, what power must be applied at the end of the cord passing

through the system to lift a weight of 300 pounds, if one end of the cord is attached to the fixed tackle block?

A. Let x represent the required power. Then, x : 300 :: 1 : 6. Hence $x = \frac{300 \times 1}{6} = 50$ pounds, answer.

Q. 146. What is an inclined plane, and what is the law governing a body in equilibrium resting on its surface?

A. An inclined plane is a smooth, hard surface making an acute angle with the horizon, and it is used in the performance of work in raising heavy bodies against the force of gravity. The work done in raising a body from the bottom to the top of the plane is equal to the weight of the body multiplied by the vertical distance through which it is raised, which is the altitude of the inclined plane. But this work is equal also to the power required to move the body up the inclined plane multiplied by the length of the plane. Or, if p is the force acting parallel with the surface of an inclined plane, w a weight resting on the plane, h the height of the plane, and c its length, then pc = wh, or p : w :: h : c. Hence the power acting parallel with the surface of an inclined plane required to hold a body in equilibrium on its surface is to the weight of the body as the altitude of the plane is to its length.

Q. 147. If the altitude of an inclined plane is 3 feet, and its length 10 feet, what force acting parallel with its surface is required to balance a weight of 2,000 pounds resting on it?

A. Let the required force be represented by x. Then, by applying the static law of a body resting on an inclined plane, we have x : 2,000 :: 3 : 10. Hence $x = \frac{2{,}000 \times 3}{10} = 600$ pounds, answer.

Q. 148. What is a wedge, and what is the law governing it?

A. A wedge is a triangular solid, used for moving a great weight through a short distance. The power which operates it generally acts parallel t the axis of the wedge, while the weight which it lifts may be regarded as acting perpendicular to its axis. For a given thickness of wedge, the longer its axis the greater will

be the advantage in the action of the applied power. The work done in driving a wedge equals the work done in overcoming its resistance. That is, the energy required to drive a wedge its full length equals the work done in moving its resistance through the thickness of the wedge. If c represents the length and h the thickness of a wedge, p the force required to drive it and w the resistance offered, then $pc = wh$, or $p : w :: h : c$. Hence the force required to operate a wedge is to the resistance offered it as the thickness of the wedge is to its length. But if the power be applied in repeated blows, then no definite law of the wedge can be given.

Q. 149. What power must be applied to a wedge 12 inches long and 3 inches thick to sustain in static equilibrium a resistance of 2,000 pounds?

A. Let x represent the force required. Then, by the law of the wedge, $x \cdot 2{,}000 :: 3 : 12$, or $x = \frac{2{,}000 \times 3}{12} = 500$ pounds, answer.

Q. 150. What is a screw, and what law governs it?

A. A screw is a cylinder having a spiral thread winding regularly around its circumference. This thread fits into a corresponding groove in a nut which can be moved from one end of the screw to the other. The power is applied at the end of a lever attached to the screw, so the work done in turning the screw once around equals the power multiplied by the circumference described by the end of the lever. The same amount of work is done in raising the body by one turn of the screw, which is equal to its weight multiplied by the distance between the threads. If c represents the circumference described by the power p, and w the weight lifted by the screw whose threads are h units apart, then $pc = wh$, or $p : w :: h : c$. Hence with a screw in equilibrium, the power is to the weight as the distance between the threads is to the circumference described by the power.

Q. 151. If a screw having threads one inch apart is driven by a power of 30 pounds applied at the end of a lever 5 feet long, what weight will it lift?

A. 5 feet equals 60 inches. If the weight that can be lifted is represented by x, then by the law of the screw $30 : x :: 1 : 2 \times 60 \times 3.1416$, or $x = 30 \times 2 \times 60 \times 3.1416 = 11{,}309.76$ pounds, answer.

CHAPTER IV.—MINING TERMS AND OTHER INFORMATION.

LESSON X.

Q. 152. Name and define the principal terms used in working coal mines.

A. *Blow-out* is a term applied to a shot when it goes off like a gun without breaking the coal.

Brattice is a longitudinal partition in a shaft, level or airway made of wood, brick or cloth to separate the opening into two compartments to aid ventilation.

Break-through is a narrow passage between rooms or entries made by cutting a hole through the coal.

Buntons are timbers placed horizontally across a shaft, to which planks are nailed that separate the shaft into compartments. They serve to brace the sides apart and act as supports for ladders, guides and pumping machinery.

Creep is the rising of the floor between pillars extending over considerable area, causing the rooms or other passages to be partly or entirely closed. When this is produced by the settling of the roof it is called a squeeze. In each case the result comes from the heavy weight resting upon the pillars.

Entry is the main passage-way of a coal mine. It is also sometimes called gangway.

Gob is the waste obtained in mining coal, and consists of slack, rock and other impurities produced in the working. The term is also applied to the space in which the mine waste is stored.

Lagging are planks or slabs placed over the caps and against the sides of the posts of the timbering of a mine to prevent fragments of coal or rock from falling into the passage-way.

Longwall is a system of coal mining by which the whole seam is removed as the working faces advance. The roof is allowed to fall in, except where passage-ways must be kept open, or where the gob is sufficient to prevent it.

Room-and-pillar is a system of coal mining in which only a part of the coal is removed, leaving the balance to support the roof and form boundaries of passage-ways in the mine.

Shift is the time for a miner to work each day. It is also the group of men working, as the day-shift, and night-shift.

Square-sets are heavy timbers used to support the rock in large excavations, and consist generally of rectangular members so joined together as to withstand the greatest pressure from the top and sides of the excavation.

Sump is the place into which the water of a mine is gathered and pumped to the surface. It is usually in the lowest part of a mine and near the shaft.

Q. 153. Name and define the principal terms used in ventilating coal mines.

A. *After-damp* is the irrespirable gas left after an explosion of fire-damp in a coal mine, and consists largely of nitrogen and carbonic acid gas.

Anemometer is an instrument for measuring the velocity of an air current in a mine.

Black-damp is a name given to carbonic acid gas by miners. It is also called choke-damp.

Fire-damp is carburetted hydrogen gas, and is lighter than air. It is inflammable, and when mixed with air to the extent of one-fifteenth to one-thirteenth by volume, the mixture is explosive.

Intake is the name especially applied to a horizontal passage which carries a ventilating current to a mine, while downcast is the term applied to a shaft when it carries the air to a mine.

Motive column is a column of air that is equal to the difference in weight of air in the downcast and upcast shafts. It is a measure of the force that produces natural or furnace ventilation.

Regulator is a sliding door that is used to govern the amount of air admitted to any part of a mine.

Upcast is the opening through which the ventilating current passes out of a mine.

Water-gauge is an instrument used to measure the pressure producing ventilation of a mine.

White-damp is a name given to carbonic oxide by miners.

Q. 154. Name and define the principal parts of machinery used in and about coal mines.

A. *Bonnet* is a covering placed over a cage to protect it from objects falling down the shaft.

Cage is a movable appliance for hoisting in a shaft, and when supplied with safety catches, it is called a safety cage.

Chute is an incline delivery-way for conveying coal from the mine hoist to the cars.

Drum is the cylinder on which the rope or chain of hoisting machinery is coiled.

Fan is the revolving machine used to blow air into or exhaust it from a mine.

Indicator is an instrument for showing the position of the cage in the shaft at any moment.

Sheave is the grooved pulley over which the hoisting rope passes from the mine to the engine.

Tail-rope is the rope attached to the rear end of a train of mine cars, where the double rope system of haulage is used. It draws the empty cars into the mine and controls the load coming out.

Whim is a vertical drum used in hoisting, and is revolved by means of a horse or an engine.

Q. 155. What is a mine foreman or pit boss?

A. A mine foreman is the man employed regularly to direct and superintend the development and working of a mine. As commonly used in the central west, this term is synonymous with pit boss, and the party in charge of the mine work is sometimes designated by one of these terms—sometimes by the other.

Q. 156. What are the qualities and qualifications that characterize a good mine foreman or pit boss?

A. A good mine foreman or pit boss is sober, careful about the work, attentive to all his duties, considerate in his orders, and has enough foresight and stability of character to influence and govern the men. He must always be ready to take the lead in investigating danger, and willing to risk his own life rather than endanger the lives of those less skillful under his charge. He should have technical training as well as practical experience, and be constantly advancing in knowledge of processes in mining. He should encounter

the new economic and scientific mining problems as they arise, and know that the best means of mastering them is through education. The trained mine foreman always takes advantage of his knowledge to increase the results of those working under his charge, and his services are most valuable when he understands the laws governing their work. Every foreman should know as much as possible of these laws on account of the dangers surrounding the work in a mine, for the safety of the men not only depends on the skill of the officials in charge, but also on the care with which each miner performs his duty; and reasonable safety can only be assured when every one engaged at the work fully understands the danger that may result from a careless act. Most of the explosions and accidents in mines result from ignorance or carelessness which educated foremen and careful miners will avert. Education is not an absolute guarantee of success, but the man who puts the most knowledge into his profession is always the most profitable workman, for he can control natural forces and apply them daily in his work.

Q. 157. What are the duties of a mine foreman or pit boss?

A. The duties of a mine foreman or pit boss are to lay off and direct the underground workings of a mine, employ and discharge all men under his direction and prescribe their work, be kind but firm in all his relations with the miners, be careful at all times to prevent accidents in or about the mines, and send none but experienced and careful men where there is most danger. He should supply all timber required at the working faces in the mine, and examine each day all working places and traveling ways to see that they are made and kept in a safe condition. He should have charge of all the machinery in and about the mine, maintain good ventilation of all airways, conduct the air properly to all working faces, and if any obstructions occur in the air-courses, have them immediately removed. He should see that the horses and mules working in and about the mines are treated properly, keep the time of all day men, measure all entries and cross-cuts, and settle all disputes among miners in a just and satisfactory manner. He should give faithful service to his employers by taking all possible steps to produce the largest output of coal with the greatest economy consistent with the safety and comfort of the employes, and in discharging his duties conduct all operations in the mine in accordance with the requirements of law.

CHAPTER V.—ESSENTIAL MINING LAWS OF IOWA.

LESSON XI.

Mines and Mining.

Q. 158. What is the law concerning the mapping of mines?

A. "Sec. 2485. The owner or person in charge of any mine shall make or cause to be made an accurate map or plan of the same, on a scale of not less than one hundred feet to the inch, showing all the area mined or excavated, and on or before the first day of September of each year cause to be made a statement and plan of the progress of the working of the mine up to date, which progress shall be clearly indicated upon the map hereinbefore required; a failure to comply with this provision for sixty days shall authorize the inspector of the district to cause the same to be done at the expense of the owner, which may be recovered in an action against him by the person doing the work, and the map so made shall include and cover the entire mine. All maps shall be kept exposed in the office of the mine, and said maps shall be subject to public inspection. The owner of any mine which is worked out or abandoned, or his agent, shall deliver a correct map thereof to the inspector to be filed in his office. * * * *"

Q. 159. What is the law concerning escape- and air-shafts?

A. "Sec. 2486. The owner or person in charge of any mine operated by shaft, or one having a slope or drift opening in which five or more men are employed, shall construct and maintain at least two distinct openings for each seam of coal worked, which in shaft-mines shall be separated by natural strata of not less than one hundred feet in breadth, and in slope- or drift-mines not less than fifty feet in breadth, through which ingress and egress at all times shall be unobstructed to the employes, and in slope- or drift-mines shall be provided with safe and available traveling-ways; all traveling-ways and escapes to be kept free from water and falls of roof. All escape-shafts not provided with hoisting appliances as hereinafter provided shall have stairs at an angle of not more than sixty degrees

in descent, kept in safe condition, with proper landings at easy and convenient distances apart. He shall provide all air-shafts where fans are used with working fans for ventilation, and those used for escapes with suitable appliances for hoisting underground workmen, at all times ready for use while the men are at labor, and no combustible material shall be allowed to be or remain between any escape-shaft and hoisting-shaft, save as it may be absolutely necessary in the operation of the mine. A furnace-shaft, if large enough, may be divided into an escape- and a furnace-shaft, the partition to be of incombustible material for a distance of not less than fifteen feet from the bottom thereof, and so constructed throughout as to exclude the heated air and smoke from the side used as an escape-shaft. Where two or more mines are connected underground, the several owners, by joint agreement, may use the hoisting-shaft or slope of the one as an escape for the other. In all cases where escape-shafts are constructed less than one hundred feet from the hoisting-shaft, there shall be built and maintained an underground traveling-way from the top of the escape-shaft, so as to furnish the proper protection from fire for a distance of one hundred feet from such hoisting-shaft. * * * *"

"Sec. 2487. In all mines there shall be allowed one year to make outlets as provided for in section twenty-four hundred and eighty-six, but not more than twenty men shall be employed in such mine at any one time until the provisions of section twenty-four hundred and eighty-six are complied with; and after the expiration of the period above mentioned, should said mine not have the outlets aforesaid, it shall not be operated until made to conform to the provisions of section twenty-four hundred and eighty-six."

Q. 160. What is the law providing for the ventilation of mines?

A. "Sec. 2488. The owner or person in charge of any mine shall provide and maintain, whether the mine be operated by shaft, slope or drift, an amount of ventilation of not less than one hundred cubic feet of air per minute for each person, nor less than five hundred cubic feet of air per minute for each mule or horse employed therein, which shall be so circulated throughout the mines as to dilute, render harmless and expel all noxious and poisonous gases in all working parts of the same; to do this, artificial means by exhaust-steam, forcing-fans, furnaces, or other contrivances of sufficient capacity and power, shall be kept in operation. If a furnace

is used, it shall be so constructed, by lining the upcast for a sufficient distance with incombustible material, that fire cannot be communicated to any part of the works. When the mine inspector shall find the air insufficient, or the men working under unsafe conditions, he shall at once give notice to the mine owner or his agent or person in charge, and, upon a failure to make the necessary changes within a reasonable time, to be fixed by him, he may order the men out, to remain out until the mine is put in proper condition."

Q. 161. What is the law concerning the use of safety appliances, the employment of competent engineers, and the non-employment of boys?

A. "Sec. 2489. The owner or person in charge of any mine shall in all mines operated by shaft or slope, where the voice cannot be distinctly heard, provide and maintain a metal speaking-tube or other means of communication, kept in complete order from the bottom or interior to the top or exterior; also a sufficient safety-catch and proper cover overhead on all cages, and an adequate brake to all drums or other devices used for lowering or hoisting persons, an approved safety-gate at the top of each shaft, springs at the top of each slope, and a trail attached to each train used therein. He shall not knowingly place in charge of any engine used in or about the operation of the mines any but experienced, competent and sober engineers, who shall not allow any one but those designated for that purpose to handle or in any way interfere with it or any part of the machinery, nor shall more than ten persons be allowed to descend or ascend in any cage at one time, or such less number as may be fixed by the district mine inspector, nor any one but the conductor on a loaded cage or car. He shall not allow a boy under twelve years of age to work in the mines, and, when in doubt regarding the age of one seeking employment, shall, before engaging him, obtain the affidavit of the applicant's parent or guardian in regard thereto. He shall at all times keep a sufficient supply of timber to be used as props, convenient and ready for use, and shall send such props down when required and deliver them to the places where needed."

Q. 162. What are the provisions of law for weighing coal, keeping records and paying miners?

A. "Sec. 2490. The owner or operator shall, if the miners are paid by weight, provide the mine with suitable scales of standard

make, and require the person selected to weigh the coal delivered from the mine to be sworn before some person authorized to administer oaths, to the effect that he will keep the scales correctly and truly balanced, and accurately weigh and a true record keep of each car delivered. * * * * The miners employed and working in any mine may furnish a competent check-weighman, who, before entertering upon his duties, shall make and subscribe to an oath to the effect that he is duly qualified and will faithfully discharge his duties as check-weighman, and he shall at all proper times have access to and the right to examine the scales, machinery or apparatus used in weighing and seeing all measures and weights of coal mined and the accounts kept thereof; but not more than one person on the part of the miners collectively shall have this right, and such examination and inspection shall be so made as to create no unnecessary interference with the use of such scales, machinery or apparatus. The owner or agent shall, where the miner is by contract to be paid by the ton or other quantity, unless otherwise agreed upon in writing, weigh the coal before screening, and the miner shall be credited at the rate of eighty pounds to the bushel and two thousand pounds to the ton, but no payment shall be demanded for sulphur, rock, slate, black-jack, slack, dirt or other impurities which may be loaded or found with the coal. Where ten or more miners are employed, such owner or agent shall not sell, give, deliver or issue, directly or indirectly, to any person employed, in payment for labor due or as advances for labor to be performed, any script, check, draft, order or other evidence of indebtedness payable or redeemable otherwise than in money at the face value, and he shall not compel or in any manner endeavor to coerce any employe to purchase goods or supplies from any particular person, firm, company or corporation; but all wages shall be paid in money upon demand semi-monthly, by paying for those earned during the first fifteen days of each month not later than the first Saturday after the twentieth of said month, and for those earned after the fifteenth of each month not later than the first Saturday after the fifth of the succeeding month. A failure or refusal to make payment within five days after demand shall entitle the laborer to recover the amount due him, and one dollar per day additional for each day such payment is neglected or refused, not exceeding the sum due, and in any action therefor the court shall tax as a part of the costs a reasonable attorney fee to plaintiff's attorney."

LESSON XII.

Q. 163. What is the penalty for attempting to defraud a miner on the correct weight of coal, or for interfering with the proper operation of a mine?

A. "Sec. 2491. The owner or person in charge of any mine, who shall have or use any scales or other appliances for weighing the output of coal so arranged that false or short weighing may be done thereby, or shall knowingly resort to or employ any means whatever by which the coal is not correctly weighed, reported and recorded as in this chapter provided, or any weighman or check-weighman who shall falsely weigh, report or record the weights of coal, or connive at or consent to such false weighing, reporting or recording, or any such owner or agent who shall fail to comply with the provisions of this chapter, or either of them, or shall obstruct or hinder the carrying out of its requirements, or any one who shall or shall attempt to compel or coerce any employe of any owner or person operating a mine to purchase goods from any particular person, shall be punished by imprisonment in the county jail not exceeding sixty days, and by a fine not exceeding five hundred dollars; or if any miner, workman or other person shall knowingly injure or interfere with any air-course or brattice, or obstruct or throw open doors, or disturb any part of the machinery, or disobey any orders given in carrying out the provisions of this chapter, or ride upon a loaded car or wagon in the shaft or slope, except as herein provided, or do any act whereby the lives and health of the persons or the security of the mines and machinery is endangered, or shall neglect or refuse to securely prop or support the roof and entries under his control, or neglect or refuse to obey any order given by the superintendent in relation to the safety of the mine in that part under his charge and control, he shall be punished by fine not exceeding one hundred dollars, or imprisonment in the county jail not exceeding thirty days."

Q. 164. What is the law concerning failure to provide for safety of employes?

A. "Sec. 2492. In addition to any and all other remedies, if any owner or person in charge of any mine shall fail to provide any of

the appliances herein required for the safety of the employes, or the appliances provided do not conform to the requirements herein specified, or such owner or agent shall neglect, for twenty days after notice given in writing by the district mine inspector of such failure, to remedy the same, such inspector may apply to the district court, or any judge thereof, in an action brought in the name of the state, for a writ of injunction to restrain the working of the mine with more persons at the same time than are necessary to make the improvements needed, save as may be required to prevent waste, until such appliances have been supplied, and in case an injury happens to those engaged in work because of such failure, the same shall be held culpable negligence."

Illumination of Mines.

Q. 165. What is the law concerning the purity of oil that can be used in illuminating mines?

A. "Sec. 2493. Only pure animal or vegetable oil, paraffine or electric lights shall be used for illuminating purposes in any mine in this state, and for the purpose of determining the purity of oils the state board of health shall fix a standard of purity and establish regulations for testing said oil, and said standard and regulations, when so determined, shall be recognized by all the courts of the state."

Q. 166. What is the penalty for selling adulterated or impure oil to be used in illuminating mines?

A. "Sec. 2494. Any person, firm or corporation, either by themselves, agents or employes, selling or offering to sell for illuminating purposes in any mine in this state any adulterated or impure oil, or oil not recognized by the state board of health as suitable for illuminating purposes as contemplated in this chapter, shall be deemed guilty of a misdemeanor, and, upon conviction thereof, shall be fined not less than twenty-five dollars nor more than one hundred dollars for each offense; and any mine owner or operator or employe of such owner or operator who shall knowingly use, or any mine operator who shall knowingly permit to be used, for illuminating purposes in any mine in this state any impure or adulterated oil, or any oil the use of which is forbidden by this chapter, shall, upon conviction thereof, be fined not less than five dollars nor more than twenty-five dollars."

Q. 167. What is the method of having mine illuminating oil tested?

A. "Sec. 2495. It shall be the duty of the state mine inspector, whenever he has reason to believe that oil is being used or sold, or offered for sale, in violation of the provisions of this chapter, to take samples of the same and have them tested or analyzed, and if they are found to be impure he shall make complaint to the county attorney of the county wherein the offense is committed, who shall forthwith commence proceedings against the offender in any court of competent jurisdiction. All reasonable expenses incurred in testing or analyzing oil under the provisions of this section shall be paid by the owner of the oil whenever it shall be found that he is selling or offering to sell impure oil in violation of the provisions of this chapter. Such costs may be recovered in a civil action, and in criminal prosecutions such expense shall be taxed as part of the costs."

Certificated Mine Foremen, Pit Bosses and Hoisting Engineers.

Q. 168. What is the law relating to examination of mine foremen, pit bosses and hoisting engineers?

A. Chapter 82 of the acts and resolutions of the Twenty-eighth General Assembly is as follows:

"Section 1. That from and after January 1, 1901, it shall be unlawful for any person to discharge, or attempt to discharge, any of the duties of mine foreman, pit boss or hoisting engineer at any coal mine, whose daily output is in excess of twenty-five tons, unless he shall hold a certificate of competency for such position as provided in this act. But in case of the discharge, resignation or disability of any person lawfully performing such duties, the owner, agent, operator or managing officer of said mine shall have a reasonable time within which to secure the services of a certificated person to take the place of the one so discharged, resigned or disabled; and during such time a competent and capable person, whether certificated as provided in this act or not, may be temporarily employed to perform such services.

"Sec. 2. Any person may secure the certificate of competency herein provided for by appearing before the board created by section twenty-four hundred and seventy-nine of the code for the examination of state mine inspectors, and submitting to such examination as to his qualifications or producing such evidence of service, as required by this act.

"Sec. 3. The board of examiners referred to in the last preceding section shall meet at such times and places, shall adopt such rules, conditions and regulations, and shall prescribe and conduct such examinations as shall be most efficient to give effect to the spirit and intent of this act. The members of said board shall each receive the sum of five dollars per day for every day actually employed in the discharge of the duties imposed herein, together with their actual expenses incurred in the performance of such duties, which expenses shall be itemized and verified as provided by section twenty-four hundred and eighty of the code, but they shall not be allowed compensation for more than seventy days in any one year.

"Sec. 4. The certificate of competency herein provided shall be issued (1), to any person who shall satisfactorily pass such examination, written or oral, as may be prescribed by said board; (2), to any person who shall produce satisfactory evidence that he has, for a period of four years immediately preceding the examination, continuously and capably performed the duties of mine foreman, pit boss or hoisting engineer, as the case may be.

"Sec. 5. Every person applying for a certificate under this act shall pay to said examining board a fee of two dollars, and every successful applicant shall pay to said board an additional fee of two dollars; all of said fees to be accounted for and covered into the state treasury. Each certificate issued under this act shall be recorded in the office of the examining board, and shall show the name, age, residence and years of experience of the person to whom it was issued.

"Sec. 6. No owner, agent, operator or managing officer of any coal mine to which this act applies shall employ any mine foreman, pit boss or hoisting engineer who does not hold the certificate herein contemplated. And any person violating any of the provisions of this act shall be punished by fine not exceeding five hundred dollars, or by imprisonment in the county jail not exceeding six months, or by both fine and imprisonment, in the discretion of the court."

CHAPTER VI.—EXPLOSIVES AND THEIR USES.

LESSON XIII.

Q. 169. What is an explosive, and what should be its characteristics for use in coal mining?

A. An explosive is a substance that is capable of being converted suddenly into gases by heat, a fuse, a detonator, or by electricity, and its value is measured by its safety, convenience, density, volume and temperature of gases evolved, and the rapidity of their production. For coal mining, a slow-burning powder is commonly used, provided there is only a small amount of gas and dust present. Such an explosive gives a larger yield of marketable coal than one that is instantaneous because it develops gases gradually during its explosion and, therefore, equalizes the pressure. Its strength not only depends on the quantity of gases evolved, which in themselves afford great pressure to the space in which they are confined, but the high temperature imparted to them at the moment of production further adds greatly to their expansion and usefulness in mining. An ideal explosive should not be affected by atmospheric moisture nor by changes in temperature, and it should not be capable of firing the gases or dust of a mine. Neither should it generate a large volume of poisonous or explosive gas, like carbonic oxide, nor emit burning particles when fire-damp or coal-dust is present; and its price should be the smallest consistent with the work it can do and the safety of the men employed in the mine.

Q. 170. What is the composition of powder, and what are some of its physical and chemical characteristics?

A. The average composition of blasting powder is about sixty-five per cent of nitre, twenty per cent of sulphur, and fifteen per cent of carbon. The grains are made large and glazed with graphite to produce slow action and retard ignition, and its explosive force is

sometimes reduced by mixing it with saw-dust, lime, powdered glass, or other inert bodies. A decrease in the per cent of nitre or an increase in the size of the grains makes a slow-burning powder. The volume of gases generated can be increased by lessening the nitre and increasing the sulphur, and this change in composition reduces the temperature of the exploded product, which thus renders the powder safer to use. Any powder is liable to produce burning particles capable of igniting fire-damp or communicating flame to the fine dust of a coal mine, which renders its use unsatisfactory when these are present. It ordinarily explodes at about 600 degrees F., and when of good quality is regular, hard, does not soil the hand, is dry, and small quantities can be exploded on paper without soiling it.

Q. 171. What products are formed in the explosion of powder, and what is the force developed by it?

A. In the explosion of powder more than one-third of the gases developed is highly poisonous carbonic oxide, and about seven per cent of the remainder is poisonous hydrogen sulphide. Nearly one-half of the gaseous product formed is directly inflammable or becomes explosive when mixed with the air. When an ordinary charge of one and one-fourth pounds of powder is used that results in a blow-out shot, about ten cubic feet of explosive air is the result, and when there are red-hot particles projected from the burning powder, they may ignite fire-damp, and the flame thus produced is often sufficient to ignite the fine particles of coal-dust that float in the air. As a result of powder explosion only about two-fifths of the mixture is converted into gases, the remaining three-fifths existing as smoke or unburned constituents. Estimating the volume of this gas under standard conditions, it occupies about 280 times the bulk of the powder employed, and the pressure developed is, therefore, $280 \times \frac{5}{2} \times 14.7 = 10{,}290$ pounds, or 5.145 tons from one cubic inch of powder. But the temperature is raised 4,000 degrees F. which is sufficient to increase the pressure in a confined cavity 9.1 times, or $5.145 \times 9.1 = 46.8+$ tons per square inch.

Q. 172. What causes blow-out shots, and what is the importance of preventing them?

A. Blow-out shots result from a number of causes, among which may be mentioned improper setting, badly tamping or stemming the charge, and insufficient or excessive powder for the bore-hole. The shot should be so located as to break off and remove the coal where desired, and so directed that in case of a blow-out the full force will not pass directly into the airway. Next to the powder when such is used should be placed a soft, dry material to hold it in place. Then upon this should be successive plugs of a good tamping material, like clay, brought into place by a wooden rod or brass bar. Iron or steel should never be used. The tamping should contain no coal, slack or coal-dust as these are liable to produce sparks which, if blown into a gaseous atmosphere, may result in an explosion. When the hole is too deep or so set that the powder applied is insufficient or too much, or the charge has been insufficiently tamped then there is an almost invariable projection of the highly heated products of the explosion, including more or less flame and sometimes particles of burning matter. The charging, stemming and firing of shots have always been a source of danger in mines, and they require careful study and should always be under the approval or direction of the mine foreman or pit boss. Blow-out shots are always dangerous in gaseous or dusty coal mines, since they are extremely liable to ignite the gas and are the most frequent cause of dust explosions. The flame of a blow-out shot will ordinarily project twelve or thirteen feet, and if there is six per cent of inflammable gas in the air it will extend forty or fifty feet. It is essential that the mining of coal should be done without adding too large an amount of dangerous or explosive gases to the air, and care in the handling and use of explosives is a matter of prime importance since the safety of the entire property and the life of the employes depend largely upon it.

Q. 173. What precautions should be observed to insure the greatest safety during the firing of shots?

A. There are no practical means which can be observed that will insure safety against blow-out shots in a dry and dusty coal mine that generates fire-damp when powder is used as an explosive. The firing of powder in such a mine is always liable to result in disaster when the air contains no more than two per cent by volume of explosive gas, for this is sufficient to lengthen the flame and create

a disturbance that will communicate the explosion to the coal-dust. In case a sudden outburst of gas is encountered, shot-firing should be suspended until the place can be thoroughly ventilated, and before operations are resumed explosive coal-dust should be removed from all parts of the mine or at least rendered harmless. Yet the removal of dust cannot be so thoroughly done as to insure safety, and sprinkling, although it has sometimes met with success alone, is so difficult of adoption at the working places where the danger originates that it is not generally resorted to. In mines that generate explosive gas it is unsafe to work with naked flames or use fuses, and in all dangerous workings the shots should only be fired by competent men between shifts when the miners are away from the seat of danger. For this purpose straws, squibs and fuses are used, but the only safe and satisfactory means is the electric shot-firer, which enables the workmen to get out of danger before the explosion takes place. The electrical also offers superior advantages over other methods of firing inasmuch as many shots can be exploded at once, as is desirable in removing pillars or causing them to run, and the yield of coal is larger, and less time is used in the work.

Q. 174. What other explosives than powder are used in coal mining, and under what circumstances are they best?

A. Where the conditions are such that it is unsafe to use powder on account of fire-damp and coal-dust, one of the high explosives may generally be used with safety. These compounds, represented by dynamite, gelatine dynamite, gun-cotton, tonite, ammonite and the like, when used under water with proper tamping, afford a complete safeguard against such dangers as result from the use of powder. They should be fired only by an efficient electrical apparatus, and as they do not produce any appreciable amount of explosive or poisonous products they insure protection of property and safety of men. The reason these high explosives are not generally used in coal mining is because their sudden action increases the percentage of fine coal, and they are more expensive than powder; but in some of the older coal-producing countries legislative enactment requires their use in dangerous mines where all kinds of powder are excluded.

CHAPTER VII.—MINING COAL BY ROOM AND PILLAR METHOD.

LESSON XIV.

Q. 175. Under what conditions is the room and pillar method of working best adapted to coal mining?

A. The room and pillar method, which is also known as the pillar and stall, pillar and chamber, post and stall, bord and pillar, and stoop and room method, is especially suited to thick seams of coal that are strong and overlaid with a good roof. It is also applicable to seams of tender coal bearing a strong roof. The room and pillar method is to be preferred for seams near the surface, especially when buildings are overhead, or when much water exists at the surface or in the upper strata, where a general subsidence would be ruinous to the plant. It is also the best method for working seams that are highly inclined, and for those that are broken with faults, on account of affording the best conditions for following them and extracting the coal. It can be used for extending the workings to the boundary limits, and its roadways are less expensive to construct and keep in repair than those of longwall mines. It produces fewer accidents, is more satisfactory for shallow mines where land is valuable than other methods, and it is the process most commonly used in the United States, where it affords a good marketable coal from its rooms and roadways. But owing to the loss of coal in pillars when they are not drawn, this method of mining is becoming less popular in countries where the supply of coal is limited.

Q. 176. In what way should a new mine be opened to afford the best means of working by the room and pillar method?

A. After a coal field has been fully prospected and found productive, the first thing is to determine the position for a shaft and select a place for the development of the mine. When the seam is practically level, the shaft should be in its center so as to afford the easiest means of underground transportation. Under such conditions the direction of the main roadways is quite immaterial, except

that it should be along the lines of cleavage when such are well defined. But if the seam is inclined, then the working shaft should be near the center of the lower side of the field so as to make the underground haulage as easy as possible and allow the water to accumulate near it by gravitation. Another shaft should be sunk along the dip at least 100 feet from it, the lower one acting as the downcast for working, and the one on the rise as the upcast for ventilation, and as a means of escape. These shafts should be connected by a heading through the coal, which will provide for ventilation by enabling each shaft to serve the purpose for which it was intended, as the air will descend through the downcast and ascend through the upcast by the force of terrestrial heat. From the bottom of the main shaft, levels are run at right angles to the dip which are to be the roadways through which the product of the mine has to pass. These are the same on each side of the shaft, and each half of the mine, which is developed from these two levels, should be symmetrical in every respect. All of the larger mines are opened with double entries. That is, the main entries are driven in pairs suitable for the most economical working of the rooms and removal of the pillars. Sometimes in very gaseous mines, where a large output is expected, a triple entry system is used in which the main entry acts as an intake and the lateral ones serve the purpose of return air courses. From the main entries, whatever their plan may be, the development of the mine must begin, and the economical extraction of coal will depend on local conditions as well as on the working system adopted.

Q. 177. What should be the size of shaft pillars for coal mines of different depths?

A. After a shaft has been sunk, the levels and entries, usually four in number at right angles with each other, are extended to the working body of coal, but no mining should be done near the shaft, except for the opening of these roads. The size of the pillars should be such that the shaft and its surroundings will remain unaffected by the removal of pillars in the working field some distance beyond. The size of shaft pillars depends on a number of factors, including the depth and inclination of the seam, the nature of the underlying and overlying strata, and the texture and thickness of the seam of coal. For a shallow mine up to 300 feet deep, it is best to leave pil-

lars forty yards square, and for flat seams these should increase one yard for every twelve feet in additional depth. So for a shaft 400 feet deep, the pillars should be forty-eight and one-third yards square; for a shaft 500 feet deep, the pillars should be fifty-six and two-thirds yards square; and for a shaft 600 feet deep, they should be sixty-five yards square. For very deep shafts, some engineers prefer to use the rule that the size of shaft pillars measured in yards shall be equal to twice the square root of the depth of the shaft measured in feet multiplied by the square root of the thickness of the seam of coal also measured in feet. Thus for a shaft 900 feet deep reaching a seam of coal nine feet in thickness, the shaft pillars should be 180 yards square. Great care is required in determining the size of the shaft pillars, and local experience is often of much service in the work.

Q. 178. Outline a plan of working a coal mine by the room and pillar method.

A. The details that should be adopted in working a coal mine by the room and pillar method will depend on a number of circumstances, including the proposed capacity of the property, the thickness and character of the coal, the inclination of the seam and the amount of gas present. For level seams of coal there are generally from the limits of the shaft pillars two pairs of headings driven parallel with each other to opposite parts of the field. One of the openings is used as the main airway and for draining the mine, while the other, the main entry, acts as the return air course and for haulage purposes. These headings are connected at regular intervals for purposes of conveying the air through the mine, for drainage and for removing the coal. At regular intervals along these headings, rooms are driven perpendicularly to the air courses and then extended parallel with each other. Between these rooms at some distance apart, narrow passages parallel with the entries are made, called break-throughs, for the purpose of ventilation. From these passage-ways and rooms the coal is extracted, while the pillars between them are left temporarily at least for supporting the roof. After a field has been thoroughly worked over in this way the pillars are generally extracted to recover the coal, allowing the superincumbent strata to drop down on the floor of the mine. Sometimes for gaseous mines the field is laid off in panels or small areas

separated from each other by strong barriers of coal some forty to sixty yards in thickness, and each of these is worked by itself by whatever system is to be preferred. In this panel work the dangers from an explosion are confined to the area in which it may occur, as each panel is ventilated by itself. After an area has been mined and the roof has fallen in, the barrier walls and stump pillars should be removed as rapidly as possible.

Q. 179. What should be the size of roadways and pillars in bituminous coal mines?

A. The dimensions of roadways in coal mines depend on three things, viz., the thickness of the coal seam through which the levels are driven, the strength of the roof and its load, and the means adopted for transporting the coal out of the mine. The size of roadways must, therefore, be settled by local conditions, but generally where mules are used, they are from five to six feet high and from seven to eight feet wide. The chief considerations that determine the pillars are the weight which they must support and the character of the roof and the floor of the mine. Their dimensions should be such that they will not only support the weight of the rock directly above them, but also the weight over the rooms. Every square foot of roof sustains about eight tons for each 100 feet of overlying strata. Thus, at 350 feet deep each square foot of pillars will be subjected to a weight of about forty-five tons when the rooms are twenty feet wide. To meet such requirements, the pillars usually range from forty to seventy feet long and are from ten to thirty feet wide, but their exact dimensions must depend on local conditions. When they are too small they crack and break up, large pieces fall from them, and finally they are crushed into small coal and the roof falls in. When the floor is weak and the pillars are small there is liable to be a creep in the mine, and if the roof will not support the strata above, the rooms and entries may be closed by the process of squeezing. To prevent these obstructions, and yet not use too much coal for supports, requires a proper size and strength for the pillars. Stronger columns are required under a firm roof than under a weak one, in thick seams than in those that are thin, in brittle coal than in a tenacious variety, in seams that are continuous than when partings exist, and they should always be made larger for a soft, flexible floor than for a weak and friable roof.

LESSON XV.

Q. 180. When should the pillars be drawn in a coal mine?

A. In gaseous mines the pillars may sometimes remain until the field has been developed for a considerable distance from the shaft, so as to facilitate the ventilation. So also for a soft, weak coal the removal of pillars may be delayed a short time, because as they are taken out the extra weight transmitted to the remaining ones along the passageways may be sufficient to crush them, especially when the roof is strong and inflexible. In most other cases, the sooner the pillars between rooms are removed the better it is for the mine. This is especially true when the roof is brittle and falls freely, for the sooner the overlying strata can be partially sustained by the gob, thus relieving the pillars along the haulage ways and main entries, the safer it is for them and the longer they last. Exposure to alterations of temperature and moisture so much reduces the resistance of coal and shortens the time during which it will sustain a great pressure that safety requires room pillars to be removed as quickly as possible after their vicinity can be abandoned. By drawing these pillars the working district is concentrated, and thus better means are afforded for keeping the limited working area in proper condition. It also simplifies the means required for ventilating the mine and thus makes the air currents purer and more efficient.

Q. 181. In approaching an abandoned working that is likely to contain an accumulation of water or gas under pressure, what precautions should be taken to guard against danger?

A. Maps and accurately made surveys should be used as guides in locating danger in a mine, but when abandoned places are closely approached, a heading should be run in advance with bore-holes extending from fifteen to twenty feet ahead of the working face. These holes are generally one and one-half inches in diameter, and should be so located that one will be in the center of the heading, running directly to the front, and one near each of its sides, making an angle of twenty to thirty degrees with the line of advance. At distances of about eight feet apart, flank bore-holes may be driven, and when the seam of coal is thick, two or more sets of such holes

should be put in one above another. The men conducting the work should be on the watch for indications of water or gas, and be provided with plugs to stop the hole in case a fountain is struck. In pitching seams when the pressure is known to come only from one direction, flank bore-holes are required only on one side of the heading, and if the pressure is known to be great and the coal is weak, much care in drilling is required to insure safety.

Q. 182. What can be said of the importance of good roads in and about a coal mine, and how should the track be laid?

A. Good roads in and about a coal mine are second only in importance to good ventilation, for if they are poorly constructed the coal cannot be transported cheaply and quickly. Poor roadways and improperly constructed track are not only a constant source of annoyance and delay, but oftentimes are the means of accidents, and in the end prove very expensive to the management. It is, indeed, an axiom in coal mining that the financial success or failure of a plant depends to a large extent on the tracks used and the skill exercised in maintaining the roadways. The cross-ties should be of good material, and it is preferable to have them sawed instead of being prepared by hand, since their faces are then in a perfect plane on which the full bearing weight of the rail can be secured. They should be laid at first as low as will ever be desired, ordinarily from twenty-four to thirty inches from center to center, and in rounding curves they should be placed radially with the broadest ends outward. The rails should be laid level, and joints broken as near half their length as possible, thus placing the end of one rail opposite the middle of the next. In laying the iron, the spikes should be placed about an inch from the edge of the tie so that the inner ones shall be near one side and the outer ones near the other, and they should never be driven so deep as to bend and injure the heads. At the opposite end of a tie where the rails join, at least three spikes should be used—two on the outside and one on the inside—but it is better to use four spikes and a fishplate there also, as they will hold the tie more firmly and give better satisfaction.

Q. 183. What causes explosions in coal mines?

A. Fire-damp has long been recognized as the principal cause of explosions in mines where it prevails, and this insiduous gas gives no warning of its presence until it accumulates in sufficient quantity

to act on a flame. When mixed with air to the extent of about eight per cent it can be ignited, while twelve per cent gives a mixture of maximum explosiveness. Whenever this gas explodes in a mine a high temperature is produced and great expansion of the air takes place in every direction, but the walls confine the force to the roadways and air courses, in which a tremendous velocity is often developed that results in loss of life and destruction of property. When there is only a small amount of fire-damp at the point of ignition, its force of explosion is soon exhausted, unless there is a large volume of air passing through the mine, or dust continues the explosion. Fire-damp requires air to support its combustion, and when the oxygen of this has been exhausted the explosion ceases. But if ignition takes place in the edge of a body of fire-damp that is being extracted by a strong ventilating current, then the whole body of gas is sure to explode with very serious results. In providing ventilation for the dangerous parts of a mine, it is, therefore, important to use only enough air to meet the requirements of the men and animals at work. Gas explosions may be started by a flame, by a blow-out shot or by improper firing, and little damage is generally done at the point where they occur, but in dusty mines force is accumulated, and the maximum velocity and intensity increase for fifty to 100 yards from the place where they start. The force of the rapidly moving air produced by the explosion carries with it and sets in motion the coal dust, and the heat of the flame liberates the gas from this, which intensifies the power of the explosion. In this way coal dust adds greatly to the strength of the gas exploded in a mine, and by its power creates force as great or even greater than gas alone can produce, and the explosive wave lifts all the dust in its progress into eddying currents that, by burning, continually produce destruction until the limits of the mine are reached. Dust alone can also create an explosion by being ignited under conditions that will liberate its volatile combustible matter sufficiently rapid to communicate a flame from particle to particle. In this way it is probable that explosions occur in the non-gaseous mines of the central west.

Q. 184. How can mine fires be extinguished?

A. When small gob-fires occur in a mine they can generally be extinguished with water or with wet cloths thrown over them, but

when they have attained such headway as not to be overcome by such ordinary means they should be immediately confined to one place by building masonry dams that will enclose them. These dams will be effective when the strata are sufficiently non-porous or are deep enough to prevent the admission of air and allow no gas to escape. But when this means will not suffice, the burning portion of the mine should be closed and banked as tightly as possible with non-combustible material, and then flooded with water to extinguish the fire. Water is generally the best agent available, and will always be effective when the internal conditions of the mine are such as to allow it to flow to the burning part; but if the air is confined and has no means of escape, roadways and rooms above the bottom of the shaft cannot be reached by it. On re-opening the mine, the burned parts may burst into flame, unless sufficient time has been given for the fire to die out and for the heat to become dissipated. For mines where water is not a satisfactory fire extinguisher, carbonic acid has given excellent results, since it can be forced to all of the roadways and workings, and is a perfect non-supporter of combustion. This gas is produced by the decomposition of limestone with dilute sulphuric acid, and can be prepared easily wherever desired.

Q. 185. What precautions should be taken in re-opening a mine after a fire or an explosion?

A. In entering a mine after an explosion, the greatest precautions should be observed to avoid accidents. First, a light should be lowered slowly into the shaft and observed to detect whether there is any explosive or poisonous gas present. Then, if conditions for entering the mine are favorable, ventilation should be restored by forcing air down the shaft, and each passageway entered with caution, always carrying the air in advance and testing it as well as the roof for safety. Brattice should be installed to control and and direct the air currents as the party advances. In re-opening the mine, it should be divided into sections, the rubbish of each part cleared away in its turn, while all the other parts are cut off by partitions, and in all that is done extreme care is required to insure safety of the men engaged at the work.

CHAPTER VIII.—MINING COAL BY LONGWALL METHOD.

LESSON XVI.

Q. 186. Under what conditions is the longwall method of working best adapted to coal mining?

A. Longwall mining is the only method that can be applied to coal seams at great depths, and it is suited to thin seams of coal that cannot be worked profitably by other processes. It is best for seams that are immediately overlaid with strata that fall readily as the coal is removed, and it is used extensively for working thin seams that are separated by a layer of rock, and for those overlaid with ironstone that is to be removed with the coal. This method can be applied best to seams free from faults, and it produces little injury to the overlying strata, because they settle gradually. Longwall mining admits of nearly all the coal being extracted from the mine, none being lost in pillars, except sometimes along roadways, and all of it is in a marketable condition. There is no simpler method of working a coal mine than this, and it affords an easy system of ventilation. Great economy is afforded by this process, because little powder is consumed in the mining and the labor required in undercutting the coal is reduced to a minimum. Fewer accidents occur in longwall than in other mines where similar conditions exist, and the system can be easily varied to meet local requirements. A tough and somewhat inflexible roof is a condition that is best for successful longwall mining, but necessity has extended this process in the central west to comparatively weak and unstable roofs. Hence this method of mining is not only used for a strong and flexible roof, but also where the roof is comparatively weak and brittle.

Q. 187. Describe the longwall method of mining coal where the roof is strong and flexible.

A. The longwall method of mining differs from the room and pillar method in removing all, or nearly all, the coal as the development takes place. Instead of the product being taken from the working face through rooms that are opened, it is removed along the face to numerous roadways that connect with the entries. As most commonly used, two shafts are sunk and a rectangular pillar left with entries running through it at right angles with each other. One of these is used as the downcast, the other as the upcast, and from the sides of this block of coal, long and narrow rooms are driven with roadways between them, the air being conducted always along the face of the coal, which as the property is developed assumes a circular form with the pillar in the center. A modification of this plan is adopted in some parts of the central west, particularly in Missouri and Kansas, in which entries are driven at right angles with each other from the bottom of the shaft for a distance of twenty to fifty feet. This distance depends on the character and strength of the roof, the depth of the coal, the nature of the underlying clay and the anticipated length of time the mine may be operated. From the ends of these shaft-pillar entries, cross-cuts are driven connecting the ends of adjacent roadways, thus leaving a rectangular block of coal to support the shaft and its surroundings. From the exterior of these cross-cuts the coal is mined radially from the shaft, the four entries being advanced with the face and kept open by gob walls, or sometimes by leaving road pillars of coal as supports. When the mining has advanced for a distance of about 800 feet, making a face between entries of 1,100 to 1,200 feet, the roadways are divided into two pairs, each branch making an angle of forty-five degrees with the original entry. Each branch is kept open with gob walls, and when driven the same distance as before, it is again bifurcated, the extension now being parallel with the original entry. The process of enlarging the workings thus continues until the limits of the property are reached, unless the coal seam is so shallow that it is more economical to sink a new shaft than to continue using the old one. This method is called longwall advancing, and is most generally used because the operator does not have to wait long for his results, since the narrow work is only completed as the rooms are developed. But for gaseous and unsafe mines it is commonly conceded that the method of

longwall retreating should be used on account of its greater safety. In this method, instead of opening up the mine outward from the shaft pillars, the entries are extended to the boundaries and the coal worked back toward the shaft. This method is used when the field is not large and there is sufficient capital to conduct the work, and it offers the advantage of leaving behind the excavated part of the mine, which is always the most dangerous when explosive gases are present.

Q. 188. What is the method of driving longwall entries for thin seams of coal?

A. The method of driving longwall entries varies with local conditions, depending on thickness of coal and character of the roof and floor of the mine. In no case is the seam of coal sufficiently thick for a roadway, and it is necessary to cut down the roof or take up the floor sufficiently for this purpose. When the floor is hard and difficult to remove, and the roof is strong, but soft and flexible, it is customary to make the extra passage-way above the coal, but when the roof is hard and strong and the floor easy to excavate, it is better to lower the track below the coal. The height of these entries varies usually from four to six feet, or in case where the roof falls, even seven or eight feet is not uncommon in places, but in the cross-entries and passage-ways between rooms, as well as in small mines where no mules are used, very little roof or floor is removed and the height is often limited to three or four feet. Still in all important mines it is best to remove enough rock from the top or bottom of the roadways to furnish the packing required to completely fill the gob of the rooms and hold the roof of the mine in place as much as possible. The width of entries varies largely with the character of the roof, and ranges usually from about four to ten or twelve feet. Sometimes where the roof is weak, the roadway is made five or six feet wide at the bottom and tapers up to about four feet at the top. The entries are first driven only in the coal, and the work of removing it consists first in undercutting and then shearing it on each side of the entry. The block of coal thus outlined is wedged or blown down and removed. Following this operation, the slate roof is shot down or the clay of the floor is lifted in the main entries and sometimes in the cross-entries for thin seams of coal and taken away for packing

the roadways. But in the rooms the miner merely brushes down the roof sufficiently for removing the coal and to provide room for the temporary track which he lays. The company furnishes the material for constructing the track, as well as the props required for the work, but the miner puts them in place.

Q. 189. Describe the longwall method of mining thin seams of coal where the roof is weak and brittle.

A. In longwall mining where the roof is weak and brittle a method is pursued in which little space is left between the advancing face and the packing that follows it, and the product is removed through small roadways that are close together and perpendicular to the face of the coal. The main entry is driven in opposite directions from the foot of the shaft for a distance of 150 to 175 feet. Then mining begins by attacking the coal on each side of the entry beyond the shaft pillar. Walls are constructed from the waste material or gob of the mine for the purpose of sustaining the roof and preserving roadways, and as the work advances, passages on each side perpendicular to the entry are left with packed walls at intervals of about forty feet. The spaces between these are known as rooms, and the method of mining the coal from them is called the room method. At a distance of about 100 feet on each side of the shaft along the main entry, cross-entries are driven parallel with the rooms, and kept open by packed walls which extend to the limits of the mine. Between these cross-entries, the rooms are worked out in a direction at right angles to the main entry. Each room is made about 200 feet long, being limited by roadways that connect the cross-entries. In thin seams the coal is gathered in boxes at the working faces and taken out through the openings between rooms to the roadways and cross-entries, and the object in limiting the size of the rooms is to enable the miner to haul out his boxes of coal and gather them at frequent intervals for removal. As the mine is developed, the main entries are extended and new cross-entries put in, but instead of the rooms in these being driven at right angles to the main entry, they are now generally made parallel with it, although some of the outer ones may be perpendicular to it. In this class of mines, the refuse material or gob is packed as the coal is removed, and the roof immediately settles behind the working face.

LESSON XVII.

Q. 190. What is the longwall method of extracting coal from rooms in mines?

A. In longwall mining the coal is usually undercut for a distance of eighteen to twenty-four inches along the face of a room, and is wedged down or falls from the weight of the superincumbent rock. The undercutting is usually done in the clay when this occurs immediately underneath the coal, but when it is excessively hard or replaced by a rock difficult to cut, the holing may be done directly in the lower bench of coal. This method, however, is always objectionable, since it causes a large percentage waste of the fuel. The undercutting is almost always accomplished by hand, yet in some places where the seams are not too thin, it is done with machines. As these devices usually remove a thick layer of clay or rock, they furnish together with the overlying slate that falls with the coal, more refuse than can usually be packed away in the mine, and hence the method becomes expensive where this has to be hauled to the surface and dumped. Some objections are also made to machines on account of incompetent and unwilling labor, yet where the conditions are satisfactory, machine cutting is gaining favor and may be quite extensively used in the near future. After the coal has been undercut and wedged down, the miner loads and usually removes it to the entry. The gob is then packed opposite the working face, keeping the passageway clear, and when props are required the miner puts them in place to support the roof. These are usually set about two yards from the coal in a space that is usually from seven to eight feet wide, and as the coal is removed, the track is advanced near its face. Under ordinary conditions a miner will undercut about twenty feet of coal at a shift, although this may vary from ten to forty feet, according to the character of the underlying stratum, the thickness of the coal and other local conditions.

Q. 191. Describe the longwall method of building entry walls and packing gob.

A. The method of building walls and packing the gob is governed largely by the condition of the roof of the mine. When this is strong and flexible, props are not commonly used, but a system of parallel walls about six feet apart is run perpendicularly to the face of the coal. These are built by the miners. The large blocks of slate are used for the entry walls, which are built about two feet thick on each side of the entry and tightly wedged with the roof at the top. The side of these walls next to the entry is made smooth. The other walls are thinner and made of smaller material. Between these rows of pillars or walls, the loose and finer refuse of the mine is shoveled and packed before the roof settles down upon it. When the overlying strata are weak and brittle, entry walls are carried along the roads as in the case of strong roofs, but instead of lateral walls, a system of props is used for support. As the coal is removed, these props are placed in parallel rows about two feet apart, running perpendicularly to the face, each new prop being set about eighteen inches in advance of the last one. These supports are left in the gob, and as the work advances the small and loose waste material of the mine is thrown around them. The roof subsides shortly upon this refuse, but often leaves more or less space for the accumulation of gas.

Q. 192. What causes spontaneous combustion, and how should it be guarded against in coal mines?

A. Spontaneous combustion is the result of chemical action produced through natural causes. It was formerly thought to be produced principally by the sulphur of pyrites found in coal, but observation shows that it is also caused by the coal itself oxidizing, especially when the ventilation is poor. Spontaneous combustion occurs principally in gobs and in pillars and walls that are subjected to great pressure. The dust, slack and pyrites being in a finely divided condition offer a large surface for the air to act upon, and as carbon in its fresh condition has great mechanical affinity for gases, the oxygen is condensed and chemical union takes place, producing heat. When there is no circulation, this heat is retained until finally it becomes sufficient to ignite the evolved hydro-carbons, and combustion is the result. Pressure also generates heat, and pillars that are crushed and shattered, thus exposing great surface for the oxygen to act upon, are sometimes set on fire through chemical

action. Poor ventilation and heated air currents, especially on the return courses, are quite favorable to spontaneous ignition, and should always be avoided when possible. Still such results can only be avoided by keeping all coal dust, slack and pyrites from the packing of gob, or by making it so solid that there will be insufficient air to effect the chemical change. When there are conditions that are especially favorable to spontaneous combustion, and explosive gas is present, it is well to wall up the gob at frequent intervals and shut it off completely from all air courses so that if combustion originates it cannot spread. Enough air should be furnished to all parts of the workings to keep down the temperature, and the roof should be so well supported that there will not be enough heat generated to ignite the shattered faces of coal. When timbers and crushed coal are left in the gob, spontaneous combustion may result sooner or later, but as it generally betrays the approaching danger by the odor evolved, such fires can be averted by observing this timely warning. The remedy in all cases is to completely isolate the section where the fire occurs, by dirt walls through which the air cannot pass, and if the conditions forewarning spontaneous combustion appear on the exposed walls they should be coated with mud or clay so as to exclude the air, or sand walls should be built.

Q. 193. In what way is the haulage in a longwall mine conducted?

A. In mines having thin seams of coal and weak roof, it is generally customary for the miner to haul the coal from the working face to the roadway on sleds or in boxes, and then load it on the cars that are run in on the roadways. But in the larger mines the cars are brought to the working faces by the car pusher. When the roof is sufficiently strong to give room for the track, a number of empty cars are run along the face, where they are filled by the miner and finally removed to the roadways. As the loaded cars are removed, empty ones are brought in to replace them and turned off the track so as to allow the loaded ones to pass by as they go to the entries. In some of the smaller mines these cars are pushed along the entries by hand, and even in some of the larger ones, where the grade is toward the outlet, the cars are run out by the car pusher, but in most of the largers ones they are handled by mules. The cars are low and small, being constructed especially for low roadways. In the

entries and roadways the track is spiked in the usual manner to wooden cross-ties, but in the face workings iron tie-bars are used in their stead, which are better, since as the face advances they are easier to handle in moving the track forward. The entry and face tracks are connected with flat iron plates on which the cars can be easily transferred from one track to the other. In the wide entries, switches are laid, and when the cars come from a large number of working places, turnouts are provided at frequent intervals, so that empty cars coming in can pass the loaded ones going out of the mine.

Q. 194. What harm is done by water in a coal mine, and what is the usual method of drainage for longwall working?

A. Water in a coal mine is more or less objectionable, since it usually injures the roof, softens the underlying clay and produces creeps and squeezes throughout the full extent of the property. When it occurs in small quantities the drainage problem is a simple one for longwall mines. It then consists in opening small ditches or drains along the sides of the entries and roadways. These are sometimes replaced with tiling or with covered drains that gather the water and convey it out of the mine through a tunnel or slope. If it is a shaft mine, the water accumulates in a sump in the lowest part of the workings, from which place it is lifted to the surface by means of a pump.

Q. 195. What conditions should be observed in the development of a longwall mine?

A. In order to secure the best results in longwall mining, the work should be prosecuted regularly and uniformly, so that the working face may advance equally in every direction, and thus practically follow the form of a circle or an ellipse. The exact shape it should take depends on the cleavage and dip of the coal, and the nature of the roof and floor. When the proper form is not followed, the coal in some places cannot be easily detached, while in others it will split off before the undercutting is completed. Proper management of the roof is one of the essential features in successful longwall mining. Its unequal settling results from irregular work and produces inequalities in the floor and the overlying strata that sometimes offer obstruction to the haulage. Such practice results in the fracture of the roof, which should never occur when the surface is wet, or when the overlying property is of much value and has buildings upon it.

CHAPTER IX.—TIMBERING MINES.

LESSON XVIII.

Q. 196. What is the importance of timbering mines?

A. Whenever an explosion occurs in a mine and lives are lost and property destroyed, many persons unfamiliar with mining think that this source of danger is the most important to be considered. But loss of lives from fire and explosions is by no means as great as by the numerous unpublished accidents that result from falling roof by reason of insufficient timbering. Fully one-third of all the deaths that occur from accidental causes in mining belongs to this latter class, and would be largely prevented by the proper exercise of judgment in timbering and care in deciding what is required to support the roof. Excavations in a mine should not generally be left without support, because if props are introduced in time they will generally prevent disastrous results. The sudden falling of the roof or the slow yielding of pillars cannot be governed by inflexible rules, but the effect of pressure is intensified by neglect, and successful management requires timbers to be placed before movement begins. When once a creep or squeeze has commenced no amount of timbering will stop it, and the damage to the mine is enormous as compared with the insignificant item of timbers which might have prevented it.

Q. 197. How are mining-shafts timbered?

A. In firm rock, the timbers of mining-shafts are subjected to little pressure, and stability rather than strength is the object sought in doing the work, since the latter is mainly secured through ample shaft pillars. Under such conditions for a small shaft, lining with heavy guide-planks is sufficient, since this is all that is required to prevent fragments of rock from falling in, and to support the buntons, guides, ladders, etc. This lining consists generally of three-inch

planks cut in proper lengths to form the sides of the rectangular shaft, and each set is held in position by bearings and by waste materials placed between it and the walls of the shaft. The guide-planks are supported on stulls resting in notches cut in the rock at distances of twenty-five or thirty feet apart, or sometimes they are hung from an upper frame supported on the top by spiking one set of timbers to another. For bad ground these casings are made thicker, generally of timbers six or eight inches thick, with their ends notched, while the buntons are bolted to them for supporting the cage-guides, ladder-ways and pumping appliances. For shafts sunk in rock that is liable to produce much lateral pressure, stronger timbers are required, and it is customary to use frame-sets eight to ten inches square placed horizontally at distances ranging from three to six feet apart. These are supported from the timbers above by means of iron rods placed at their corners, while around them two or three inch lagging are driven that reach from one set of timbers to the next below.

Q. 198. What is the method of timbering slopes?

A. In timbering a slope it is quite indispensable to use timbers consisting of a mud-sill as well as top and side pieces, and the sill should be well imbedded in the rock to prevent it from slipping down the incline. Sometimes the sides are held in place by plugs driven into the rock, while the sets of timber are often braced against one another by longitudinal studs. The timbers are cut so that the top pieces are considerably shorter than the sills, and for an ordinary single-track slope the inside dimensions are generally about eight feet at the bottom, six feet at the top and six feet high. When the dip is not great, the height of the slope is made the same as that of the entries, but the timbers are set leaning toward the vertical on account of offering greater resistance to the forces that act upon them. When the most substantial timbering is required, the sets and props are sawed square and lagged with plank, but most frequently round timbers from eight to fifteen inches in diameter are used for the sets. The side-pieces are slightly notched into the cap and the sill, so that there is a full timber exposure on the top and bottom of the set. This is required on account of the greatest

pressure coming from the top, but the side-pieces also have to be notched into the cap and sill to prevent the sides giving way. These trapezoidal timber-sets are usually placed from three to six feet apart, depending on local requirements, but when the rock is very bad and the pressure is enormous, they are set against each other, making what is called the skin-to-skin method of timbering. Behind these timbers are placed round poles nearly touching each other, extending from the center of one set to the next, or sawed lagging from two to four inches in thickness are used.

Q. 199. Describe the timbering of roadways and entries in a mine.

A. As round timber is cheaper and stronger, and requires less preparation than that which is square, it is generally used for levels, and should be of a size amply sufficient to withstand all pressure that may come upon it. When the sides of the roadways and entries are strong, but the roof needs supporting, sometimes only a cap and top lagging are required, which should rest in excavations cut out on the sides. If one side only as well as the roof needs supporting, then it is best to excavate sufficiently at the top of the opposite side of the roadway for holding one end of the cap, and also a small hole should be cut at the bottom of the side requiring the stud. Then a set of two timbers, consisting of cap and side-piece, is inserted, in which the stud is slightly notched into the cap so as to give greatest resistance to the encroaching forces. Lagging are placed around this set of timber as in the case of slopes. For roadways and entries that need complete timbering, trapezoidal sets are used to support the lagging as in the case of slopes. These are commonly made of this quadrilateral form to reduce the length of the cap, and when the floor is soft and liable to receive a creep, mud-sills should be used. These sets of timbers are placed perpendicularly across the passageway, which is different from the method used in slopes. The sides, top and bottom pieces are notched in such a manner as to offer greatest resistance to the pressure that comes upon them, and in all cases sufficient lagging should be used to prevent an influx of earth. When the roadways are made wide enough for two or more tracks, they either receive a line of supports through the middle, or have a system of corner braces for supporting the cap in the middle. These braces either rest in notches cut in the studs or upon short props

placed on the sides for that purpose, while between the upper ends of the braces a short horizontal bar is used resting against the under side of the cap as a means of central support.

Q. 200. In what way should the roof of the underground workings be supported, and what may be said about timber-drawing in a mine?

A. The enormous weight of overlying strata in coal mines requires an efficient system of timbering and packing that will provide safety for the miners; yet, as timbering is expensive, prudence demands that it shall de done economically, and there should be as little waste as possible. Knowledge of the condition of a roof can only be gained through experience, and this enables the miner to determine where props are required in his room, and freedom from accidents depends largely upon the intelligence and judgment of the workmen. Props should always be placed in line with the direction of the pressure, so as to secure the maximum resistance, and knowledge of where and how far apart supports should be placed can only come from study, careful observation and years of experience. But the supporting timbers should not be left long in a mine, because the roof should be allowed to settle regularly and thus release the pressure on the face of the coal. If props and pillars are allowed to remain, the excessive weight upon them reduces the percentage of lump coal by the production of slack, and it causes the superincumbent rock to settle on the pillars and crush them. To prevent this, the timbers should generally be removed as quickly as possible after the coal is extracted. Still timber-drawing is always dangerous, the danger increasing with the time the props are left in the mine, and very serious accidents occasionally occur by attempting to extract props that have been left too long. The timbers in the rear rows should be removed first, and in a general way the order of their removal depends upon the advantage of allowing the roof to fall at a particular place; still experience and judgment must determine the best order of drawing pillars, especially when the waste area is large. Only one prop should be removed at a time, and it may be necessary to leave some behind in order to secure the others in safety, and when the roof is too dangerous it is best not to remove them at all on account of the accidents that may occur by so doing.

CHAPTER X.—MINE GASES.

LESSON XIX.

Q. 201. What impurities contaminate the air of coal mines?

A. The air of coal mines becomes contaminated with various impurities, among the most important of which may be mentioned marsh gas, carbonic acid, carbonic oxide, hydrogen sulphide, the products of combustion, smoke and dust.

Q. 202. What are the properties of marsh gas?

A. Marsh gas, otherwise known as carburetted hydrogen, is the most dangerous of all gases found in coal mines. It is always produced in the decomposition of vegetable matter in presence of water, out of contact with the air, and was liberated in the metamorphism of ancient vegetation into coal, but accumulated only where the conditions favored its storage. This gas is, therefore, not always present in appreciable quantity when mines are developed, and in some of the western states is practically absent. It is a colorless, tasteless, odorless gas, having a specific gravity of .558. Owing to its lightness, it diffuses rapidly in the atmosphere wherever liberated until the air becomes impregnated with it. As it is not poisonous, a man can breathe a large amount of marsh gas with impunity when it is mixed with the air. It merely acts as a suffocating agent by preventing the air from oxidizing the blood. This is a combustible gas and burns with a blue flame, but does not ignite immediately when brought in contact with fire. The gas requires an appreciable time for combustion, which property enables instantaneous explosives to be used with safety in an atmosphere containing a large amount of it.

Q. 203. What can be said of the occurrence and properties of fire-damp?

A. Fire-damp is light carburetted hydrogen, but as the term is generally used it applies to any explosive mixture of marsh gas and air. This exists wherever marsh gas is liberated in a mine, and

owing to its lightness, it rises to the highest openings and collects in cavities and undisturbed workings near the roof. For this reason, fire-damp should always be sought in the highest parts of a mine. The explosive limits of this gas depend on the purity of the marsh gas and the pressure to which it is subjected; but under ordinary conditions, when marsh gas exists in the air in proportions ranging from about seven to fifteen per cent, the mixture is explosive, and has its maximum explosibility when about nine and one-half per cent of the gas is present. At the lower limit, the force of an explosion is very weak, but grows steadily stronger until its maximum point is reached, and then becomes weaker until the highest limit is passed, when explosibility ceases altogether. Coal dust also increases the explosive range of this gas by reason of the products distilled from it. Fire-damp is the most frequent cause of mine explosions, but in many places coal-dust alone will explode from blow-out shots when the mine is dry and dusty.

Q. 204. How are mines tested for fire-damp?

A. Testing for fire-damp in a mine is usually entrusted to a special person called the fire-boss, whose position is one of great responsibility, since upon his skill rests the safety of every man employed in the mines. Fire-damp can be most easily detected with a safety lamp, which must be sensitive and in good working condition. The lamp is raised cautiously in a mine to the place suspected of containing the gas, when if present to the extent of about two per cent, it manifests itself by giving a blue tip to the point of the flame; and if present in dangerous quantity, it burns and fills the whole lamp with a blaze. From such a place the lamp should be immediately withdrawn, and it should always be held in an upright position so as not to allow the flame to ignite the gas surrounding it. The lamp should have free admission of air below the flame, and have no reflecting surfaces, because these interfere seriously with the delicacy of the test. The safest and best oils to use in these lamps are of vegetable or animal origin. Refined rape-seed oil, known as colza, and seal oil are considered standard, but these are liable to incrust the wick and thereby impair the brilliancy of the flame. This, however, can be overcome largely by adding a small percentage of petroleum or benzine to the oil, which also cheapens the product.

Q. 205. How does carbonic acid occur in a mine? What are its properties, and how can it be detected?

A. Carbonic acid, commonly known as black-damp and choke-damp by miners, is always found in mines where it is stored in the strata, and is a product of combustion of coal and the oil used in lamps. It is also generated in the firing of shots, is given off in the breath of men and animals, and is produced constantly wherever there is vegetable or animal decay. This gas is colorless and odorless, but has a distinct acid taste. Its specific gravity is 1.529, and it therefore collects on the floor and in the lowest parts of a mine, where it is liable to do most harm. When breathed in considerable quantity it acts as a narcotic, producing headache and nausea, and finally causes death through suffocation. This gas is a non-supporter of combustion, and is therefore readily detected by its causing a flame to become reduced in size and burn with a smoky appearance, or if the amount is sufficient it will entirely extinguish a flame. It can also be detected by changing lime water to a milky appearance when it is blown through it, and by turning moist vegetable blue coloring matter red.

Q. 206. Describe the occurrence, properties and detection of carbonic oxide.

A. Carbonic oxide, also known as white-damp, is a very dangerous gas on account of its harmful effects in the system, and its unsuspected presence in a mine. This gas is the result of incomplete combustion, is produced by burning gobs, by mine fires, and by the explosion of powder. When an ordinary coal fire burns with a pale, violet-blue flame, this is the gas that is being consumed. It is colorless, odorless and tasteless, and is a little lighter than air. It burns, as in the case of a coal fire, with a pale, violet-blue flame, and is highly explosive when mixed with the air. When breathed even in small quantities, it is absorbed by the blood and acts on the nerve-centers, producing drowsiness that is followed by acute pains in the head, back and limbs. These symptoms change to delirium, and death soon follows, unless the person is rescued and restoratives applied. Carbonic oxide is the most poisonous of all gases found in a coal mine, and is ordinarily detected by its effect on the flame, which it causes to become brighter and longer, and burn with a quivering tip that can be seen most distinctly by screening the eyes from its brighter portions below.

Q. 207. How are these gases liberated during the process of mining?

A. Mine gases are held in place through the impenetrability of the coal and surrounding strata; but as the coal is removed and the rocks are broken, the gases escapc and contaminate the air surrounding their storage reservoirs. By using a pick or drill in mining, cavities are sometimes opened in coal that afford a large amount of gas, and these reservoirs sometimes continue to discharge their product for a long time without seeming to diminish their flow, when they are commonly known as blowers. An outburst of gas often takes place at a working face without giving much preliminary warning, dislodging large quantities of coal in a similar manner to an explosion of powder. When the pressure is very great, a rumbling noise is sometimes heard for two or three days before the eruption takes place. Most of the violent outbursts are of marsh gas, but there are instances on record where carbonic acid has been discharged with great violence. The condition of the weather has a marked influence on the production of gas in a mine from ordinary accumulations of it. When the air is dry and heavy, the gases are held back, but when it is damp and the barometer falls, the pressure is reduced and an excessive amount of gas escapes which requires increased ventilation and more care to be exercised to preserve health or prevent an explosion.

Q. 208. What harm may be done by other impurities occurring in the air of coal mines?

A. Hydrogen sulphide is only found in mines that contain considerable sulphur in a combination that is capable of being converted into this gaseous product through the agency of water. This is a heavy gas and explodes with violence when mixed with about seven times its volume of air. It is very poisonous, producing derangement of the system when breathed in small quantities, and complete prostration and unconsciousness when taken in larger amounts. Hydrogen sulphide has a strong, disagreeable odor, resembling rotten eggs, and is, therefore, easily detected. The smoke resulting from powder-shots is disagreeable and poisonous, and should never be breathed; and coal-dust not only injures the membranes of the lungs, but is dangerous on account of its tendency to contribute to an explosion. Hence all mines containing these poisonous or dangerous substances should be thoroughly ventilated.

CHAPTER XI.—VENTILATION OF MINES.

LESSON XX.

Q. 209. Why is it necessary to ventilate mines, and what are the principles on which ventilation depends?

A. Pure air is as essential to health as is pure food indispensable to the nourishment and support of the body and the building of tissue. The object of ventilating mines is, therefore, to supply all the underground workings with uncontaminated air for the benefit of those engaged at the work. Currents are produced by the difference in pressure, which is given to the air in natural ventilation by its gravity, and in artificial ventilation by applying heat, or by giving pressure to it. Considerable power is required to create this circulation, since it is opposed by its inertia, which has to be overcome, and by its friction against the sides of the mine. The principal factors which, therefore, retard the ventilation are high speed of the current and small air-ways. Any means which enlarges the air-passages or separates them into splits that will supply different parts of the mine, overcomes some of these factors of resistance, and therefore benefits the system of ventilation.

Q. 210. What volume of air is required to ventilate a mine producing 500 tons of coal per day, and what size should the main air-way be to supply this amount?

A. An average miner will produce about two and one-half tons of coal at a shift, so to mine 500 tons, 200 men are required. In addition to these, about fifteen day men should be employed, making in all 215 men for the underground work. Then about ten mules must be kept in the mine for hauling the cars. Each man requires at least 100 and each mule 500 cubic feet of air per minute for proper ventilation. This equals $215 \times 100 + 10 \times 500 = 26,500$ cubic feet of air. This is the minimum amount that the law requires. To give a proper margin of safety, from ten to twenty per cent additional air should be forced through the mine, or say a total of 30,000 cubic feet per minute. For gaseous mines, the maximum velocity of the air-current should not exceed 450 feet per minute, but for non-gaseous ones it may range anywhere from 200 to 1,200 feet per minute,

depending on local conditions. So if the proper velocity in the airway be considered 600 feet per minute, the sectional area of the passage should be $\frac{30,000}{600}=50$ square feet, or six by eight and one-third feet in dimensions.

Q. 211. How is the velocity of an air-current measured in a mine?

A. The velocity of an air-current may be roughly estimated by burning some powder and then measuring the distance its smoke travels in a minute or fraction thereof. This will always give too great a velocity, since the center of the current which carries most of the smoke always moves much faster than the outer portion or the average current; still for approximate purposes this will answer all requirements. For accurate work an anemometer must be used. This is an instrument set with revolving vanes so arranged that they make one revolution for each foot the air-current moves. The revolving motion is communicated to a set of dials which can be easily read, and thus the velocity of the air can be accurately determined. In using the instrument, it is necessary to take the velocity in various sections of the airway. One of the best plans is to divide the air-passage into nine imaginary equal areas, and hold the anemometer an equal length of time in the center of each of the eight outer spaces, then in the center space as long as it was held in all of the others combined. By dividing the distance recorded on the dials by the total number of minutes the anemometer is exposed to the air will give the average velocity per minute. This method of estimation experience shows to be accurate and satisfactory. The anemometer should be held with its face perpendicular to the direction of the air-current, and the person doing the work should stand in a side-opening so as not to obstruct the current, and should have the instrument attached to a small rod that will reach each space to be tested. The volume of air circulating in the mine is equal to the area of the airway multiplied by the velocity thus determined.

Q. 212. What causes the natural ventilation of a mine, and how can the force that creates it be determined?

A. Natural ventilation of a mine is caused by the difference in weight of the air in the downcast and upcast shafts, which may result when the tops of these shafts are on different levels. If the air of the mine has the same temperature as that on the outside,

there can be no natural circulation within; but in winter, when the interior is generally warmer than the exterior of a mine, the air becomes heated and expands as it moves through the air-passages, and thus creates a circulation. In summer, when the outer air is the warmer, the mine cools and renders heavier that which passes within, and the ventilating current flows down the deeper shaft and out of the shallower one located on the hillside below. The difference between the weight of the air in the downcast and upcast shafts is the force that creates this ventilation, and a column of air in the downcast equal to this difference in weight is called the motive column. Let this be designated by M, the depth of the shafts by D, and the temperature of the upcast and downcast currents be designated by T and t respectively, then it is found that $M=\frac{D\ (T-t)}{459+T}$, a formula that should be remembered. Suppose the shafts are 100 feet deep, the temperature of the upcast 100 degrees and that of the downcast 40 degrees Fahrenheit. Then the motive column equals $\frac{100(100-40)}{459+100}=$ 10.73+ feet. That is, the force which produces the ventilation is equal to a column of the downcast air 10.73+ feet in length. If the shaft has an area of 36 square feet, the ventilating force is equal to $36\times10.73+=386.38+$ cubic feet of air at 40 degrees Fahrenheit. But one cubic foot of air at this temperature weighs .07968 pound, so 386.38+ cubic feet will weigh 30.787+ pounds, which is the total force in the downcast shaft creating the circulation.

Q. 213. What is meant by pressure producing ventilation, and how can it be measured by the water-gauge?

A. The pressure which produces ventilation is the force per square foot that is required to give a certain velocity to the air-current in a mine. This is commonly measured by the excessive force applied to the circulating air above that which is given to the undisturbed air outside the mine. The water-gauge is an instrument used to measure this difference in pressure, which is best determined near the mouth of the returning air-current, because this measures the full resistance of the mine. The instrument consists of a U-shaped tube open at both ends, placed on a support so that one end of the tube is in communication with the air circulating within the mine while the other end is open to the undisturbed atmosphere without. Water is placed in the tube so that a differ-

ence in atmospheric pressure in each of its ends creates a difference of level in the two branches corresponding to the difference of pressure. This difference in pressure is measured in pounds per square foot, which can be readily determined from the reading of the water-gauge. Thus the weight of a cubic foot of water, which is twelve inches square, is 62.5 pounds, or for each inch in depth there is a pressure of $\frac{62.5}{12}=5.2$ pounds per square foot. Hence the ventilating pressure measured in pounds on each square foot of an airway is equal to 5.2 times the reading of the water-gauge in inches.

Q. 214. What is meant by power producing ventilation, and how can it be determined?

A. The power producing the ventilation of a mine is the work required to set the air moving, and is measured by the number of foot-pounds of energy expended in a minute in setting the air in motion. But work has already been shown to be measured by the moving force multiplied by the distance through which it acts. This in a unit of time is equal to the total applied pressure multiplied by the velocity. Hence the work done each minute in ventilating a mine is equal to the continued product of the pressure per square foot as shown by the water-gauge, the sectional area of the airway and the velocity of the current. To illustrate, let us suppose that the water-gauge reads two inches, the sectional area of the airway is fifty-six square feet, and the velocity of the current is 600 feet per minute, what is the power producing the ventilation? Two inches of water-gauge shows a pressure of $2\times5.2=10.4$ pounds per square foot. Then the power producing the current is equal to $10.4\times56\times600=349{,}440$ foot-pounds per minute, or $\frac{349{,}440}{33{,}000}=10.58+$ horse-power.

Q. 215. A mine requires 250,000 cubic feet of air per minute for its ventilation. What horse-power is required to produce this, if the resistance shows a water-gauge reading of 2.5 inches?

A. In this problem the ventilating pressure is $2.5\times5.2=13.00$ pounds per square foot. The 250,000 represents the velocity of a current passing through an airway of one foot sectional area. Hence the work required to move the air is $250{,}000\times13.00=3{,}250{,}000$ foot-pounds per minute, or $\frac{3{,}250{,}000}{33{,}000}=98.48+$ horse-power.

LESSON XXI.

Q. 216. Under what conditions is a furnace satisfactory for ventilating a mine, and what precautions should be taken to prevent danger from explosive gases when it is used?

A. Furnaces have long been used to create a circulation of air in mines. Near the bottom of the upcast is constructed the fireplace which should be walled and separated from the surrounding coal and strata on all sides by air or sand spaces. Two overhead archways extend from the furnace to the upcast, and around the outer one sand should be packed, while a space of six inches or more is left between this and the inner arch for the air to circulate through. Underneath the grate should be placed fire-clay or iron that will protect the floor from becoming too hot. While furnaces are cheap and present advantages that often commend them, they will not produce in shallow mines a sufficient motive column to be of much service. Then their usefulness is seriously affected by atmospheric changes, and a wet upcast will always impede ventilation by creating a strong resistance to the air rising. Numerous accidents have resulted from the use of furnaces by setting fire to the solid coal, the timbers of the shaft, or the surface plant. When the returning air contains inflammable gases, it is sometimes necessary to provide the furnace with fresh air direct from the intake, and conduct the ventilating current around the grate to the upcast. A dumb-drift is used for this purpose so as to isolate the gases from the fire. The junction of this drift with the upcast should not be within fifty feet of the furnace, and in some cases safety can only be assured by carrying it from 150 to 300 feet beyond the fire before connecting with the upcast.

Q. 217. Upon what does the fire-grate surface of a ventilating furnace depend, and how can its proper area be determined?

A. It is customary in the construction of ventilating furnaces to make the fire-pit eight or nine feet in length, but the grate-bars should not ordinarily be more than five feet long. The area of a furnace depends on the amount of air that is required for the efficient ventilation of the mine, and the factors which enter into its determin-

ation are the horse-power required to move the air and the depth of the shaft. This fire-grate area varies inversely as the square root of the depth of the mine, and may be determined by the formula

$$s = \frac{34\ p}{\sqrt{d}},*$$

in which s is the number of square feet contained in the fire-grate, p the horse-power producing ventilation and d the depth of the shaft measured in feet. Thus for a mine 400 feet deep, requiring twenty-five horse-power for its ventilation, the area of the fire-grate should be $\frac{34 \times 25}{\sqrt{400}} = 42.5$ square feet, or it should be five feet long by eight and one-half feet wide. Whenever it is necessary to have more than fifty or sixty square feet of grate surface, it is better to construct and use two or more small furnaces than a large one, on account of the difficulty and dangers attending the use of a large fire in a mine.

Q. 218. What should be the dimensions of a furnace-grate necessary to ventilate a mine 400 feet deep with 80,000 cubic feet of air per minute, when the water-gauge resistance is 1.8 inches?

A. The power required to produce the ventilation is $80{,}000 \times 1.8 \times 5.2 = 748{,}800$ foot-pounds, or $\frac{748{,}800}{33{,}000} = 22.69+$ horse-power. Then the area of the grate is equal to $\frac{34 \times 22.69+}{\sqrt{400}} = \frac{771.46+}{20} = 38.57+$ square feet. As the furnace-bars are five feet in length, the lateral dimension should be $\frac{38.57+}{5} = 7.71+$ feet. The grate should, therefore, be five feet long by 7.71+ feet wide.

Q. 219. Describe the waterfall method of ventilating a mine.

A. When water is allowed to fall in divided currents or a spray in a confined space, it acts as an inspirator and carries a large amount of air with it. This principle is used in laboratory pumps, and sometimes mines are ventilated in this way where the conditions are favorable, because it is cheap and very efficient. Thus, where an abundant water supply exists above the mine that can be conducted through a shaft for the purpose, or where the water can be admitted into the ventilating shaft and then drained from the mine through an

* The expression $\sqrt{d}$ denotes the square root of d.

adit or tunnel, the waterfall is a desirable method of ventilation. Sometimes a jet of water is projected along the path of a ventilating current to produce or assist in the ventilation, but this can only be done on a small scale in a cheap and efficient manner. For small mines the water may be admitted into the shaft in a trompe, which is a vertical passageway having a grating at the top for dividing or spraying the water, while along the sides are dash-boards that continually break the current and draw in air through openings along the sides. With large mines, it is better to allow the water to fall directly in the shaft after it has been sprayed by flowing through an interwoven mass of sticks resting on the buntons at the top. In this way a powerful air-current can be produced, which often amounts to 200,000 or 300,000 cubic feet per minute when the water supply is copious

Q. 220. What are the principles governing the action of ventilating fans?

A. Ventilating fans are of two varieties. With one of them known as the force-fan, air is forced into a mine by increasing its pressure at the top of the downcast shaft. With the other variety known as the exhaust-fan, air at the top of the upcast is rarefied, and circulation results within from the pressure in the downcast, which thus becomes greater than that in the upcast. Force-fans are much used for small mines requiring but a moderate amount of air, and they have an advantage in gaseous mines in holding back gas that would be discharged by the use of an exhaust. They are of simple construction, consisting of a revolving wheel having blades set in a casing that receives the air at the center and discharges it at the circumference. Exhaust-fans are of the windmill and the centrifugal patterns. In the former, the revolving blades of the fan cut off the air as it is exhausted from the mine, while with the latter type the return air is taken in at the center and thrown off at the circumference. They are easily constructed and maintained, have a high efficiency which ranges from fifty to sixty per cent of the indicated horse-power of the engine that operates them, may be made of any size to meet requirements, and they may be made to increase ventilation by increasing their speed whenever emergencies demand it. For these reasons fans are supplanting all other forms of ventilators. Still fan ventilation is affected by atmospheric changes in the same way that furnace currents are affected by them, and a low

barometer and high temperature require an increased ventilation to secure satisfactory results. The amount of air that a fan forces into or exhausts from a mine is directly proportional to the number of revolutions which it makes. Thus if a fan making seventy-five revolutions produces 75,000 cubic feet of air per minute, it will produce $75{,}000 \times \frac{100}{75} = 100{,}000$ cubic feet per minute when its speed is increased to 100 revolutions.

Q. 221. Compare the use and efficiency of furnaces and fans for the ventilation of mines.

A. In comparing the use and efficiency of furnaces and fans for mine ventilation, it must be noticed that each system has its objections. A furnace is liable to set fire to its surroundings and cause explosions in gaseous mines when it is not properly constructed. Fans are more expensive than furnaces, and when they are stopped all ventilation ceases, which is not the case with furnaces, for the air-current continues from them for some time after the fires are extinguished. With a furnace, the force producing ventilation is due to the rarefied air in the upcast shaft which allows the atmospheric pressure on the downcast to force a current through the mine. As the motive column is a measure of the force producing ventilation, it is evident that the efficiency of a furnace increases with the depth of the upcast, so the work can be done more thoroughly in a deep than in a shallow mine. But with fan ventilators, as the depth of the mine increases, the work of moving the air also increases, because it becomes more dense the deeper we go. For every 1,000 feet in depth, the pressure on the water-gauge increases four-tenths of an inch to secure a uniform circulation, so the deeper the shaft is extended, the more work is required to ventilate a mine. When a certain depth is reached, it becomes a question whether furnace or fan ventilation is to be preferred. Exhaust-fans are safer than furnaces, have a uniform efficiency for deep and shallow mines, and are consequently generally the best means for economical ventilation. For shallow mines they are always to be preferred, for they will put in circulation a greater quantity of air in proportion to the amount of fuel consumed than will a furnace, and a good fan when operated with a condensing engine, is cheaper than a furnace for depths somewhat exceeding 4,000 feet, but for depths much greater than this, furnaces are perhaps more economical.

CHAPTER XII.—FRICTION OF AIR IN MINES.

LESSON XXII.

Q. 222. What is the relation between the pressure producing ventilation and the rubbing surface of a mine, when the velocity of the air-current remains constant?

A. The pressure required to overcome the friction of air in a mine varies directly as the total rubbing surface, so long as the velocity of the air-current remains constant. The rubbing surface is the superficial area of all the passages with which the air is brought in contact as it circulates through a mine. The extent of this varies with the length, size and shape of the airways, and is always equal to the perimeter of the air passages multiplied by their length. Thus when the length of an airway is doubled, while its sectional area remains the same, the pressure required to produce the same amount of ventilation must also be doubled. Or, if the airway be reduced to one-half its original length, only one-half as much pressure is required to ventilate the mine with the same amount of air. For equal lengths of different airways, the rubbing surfaces bear the ratio of their perimeters, which are less for those that are circular than for those that are square, while the perimeters of rectangular airways increase as the areas become more oblong.

Q. 223. Suppose there are two rectangular airways, each 5,000 feet long. One is 6 by 6 feet, and the other is 4 by 9 feet. If the pressure required to ventilate the square airway shows a water-gauge resistance of two inches, what will be the pressure in the rectangular airway, when it is ventilated with the same amount of air?

A. The rubbing surface of the square airway is $(6 + 6 + 6 + 6) \times 5{,}000 = 120{,}000$ square feet, while the rubbing surface of the rectangular airway is $(4 + 9 + 4 + 9) \times 5{,}000 = 130{,}000$ square feet. Now, since the sectional areas of these airways and the amount of air that passes through them are the same, the pressure required to produce the ventilation must vary as their rubbing surfaces. If x

equals the water-gauge pressure in the rectangular airway, then $2 : x :: 120{,}000 : 130{,}000$, or $x = 2\frac{1}{6}$ inches. But as each inch of water-gauge represents 5.2 pounds pressure per square foot, the ventilating pressure in the rectangular airway is $2\frac{1}{6} \times 5.2 = 11.26\frac{2}{3}$ pounds per square foot.

Q. 224. What is the relation between the pressure producing ventilation and the area of the airway, when the velocity of the current and the rubbing surface remain the same?

A. The pressure required to produce a constant amount of ventilation in a mine varies inversely with the sectional area of the airways, so long as the velocity of the current and rubbing surface remain the same. That is, as the area of an airway is increased or decreased, while its length and rubbing surface are unchanged, the pressure required to force a constant amount of air through the mine must be decreased or increased in a corresponding manner. Thus when the area is increased to twice or four times its original amount, the pressure required to keep a constant ventilation must be reduced to one-half or one-fourth what it was before. Or, if the area is reduced to one-half or one-fourth its former amount, the pressure must be increased to twice or four times what it was at first.

Q. 225. Given two airways of equal length and equivalent rubbing surfaces, one rectangular 6 by 7 feet, and the other circular. If the pressure required to ventilate the rectangular airway shows a water-gauge reading of two inches, what is the pressure required to ventilate the circular airway with the same velocity of current?

A. The perimeter of the rectangular airway is $6 + 7 + 6 + 7 = 26$ feet, while its sectional area is $6 \times 7 = 42$ square feet. The diameter of the circular airway of the same rubbing surface is $\frac{26}{3.1416} = 8.21+$ feet. Its area is $.7854 \times 8.21+^2 = 52.93+$ square feet. Then as these airways are of equal length and have equivalent rubbing surfaces, the pressure required to ventilate them will be inversely as their sectional areas. If the water-gauge reading for the circular one be represented by x, then $2 : x :: 52.93+ : 42$, or $x = 1.59+$ inches, which equals $1.59+ \times 5.2 = 8.26+$ pounds per square foot.

Q. 226. What is the relation between the pressure required to ventilate a mine and the velocity of the air-current, when the area of the airway remains constant?

A. For airways of equal sectional area, the pressure required to produce a uniform amount of ventilation in a mine varies directly as the square of the velocity of the air-current, multiplied by the rubbing surface. When the rubbing surfaces of different airways are equal, then it is evident that the pressure varies directly as the square of the velocity. This means that the pressure required to ventilate an airway, when the velocity of the current is doubled, is four times as great, and when the velocity is reduced to one-half, it is only one-fourth the amount. If, at the same time, the airway be doubled in length, while the velocity of the current is doubled, then the pressure required to ventilate the mine will be 4×2 or 8 times as great as before. Should the velocity be doubled and the rubbing surface reduced to one-half its former amount, then the pressure must be doubled; and, if the velocity is doubled while the airway be reduced to one-fourth its original length, the pressure producing ventilation will remain unchanged.

Q. 227. There are two airways, each 1,000 feet long. The sectional area of one is 6 by 7 feet, and it is ventilated by an air-current whose velocity is 500 feet per minute, while the water-gauge stands at 2 inches. The sectional area of the other airway is 5 feet and 3 inches by 8 feet, and its air-current has a velocity of 600 feet per minute. What is the pressure producing its ventilation?

A. These two airways have the same area, but the rubbing surface of the one 6 by 7 feet is $26 \times 1{,}000 = 26{,}000$ square feet, while that of the other is $26.5 \times 1{,}000 = 26{,}500$ square feet. Then, if the water-gauge reading of the latter be represented by x, we have $2 : x :: 500^2 \times 26{,}000 : 600^2 \times 26{,}500$, or $x = 2.93+$ inches. Hence the pressure required to ventilate the last mentioned airway is $2.93+ \times 5.2 = 15.26+$ pounds per square foot.

Q. 228. What is meant by coefficient of friction as applied to air-currents in mines?

A. Whenever air is forced through a mine, it encounters resistance by reason of its friction against the rubbing surfaces. The amount of force, measured in parts of a pound, required to overcome this friction on each square foot of airway when the velocity of the current is one foot per minute is known as the coefficient of friction. This varies somewhat with the kind of rock through which the air passes and with the smoothness of the rubbing surfaces. Different investigators have obtained results that vary somewhat from each other, but the one most commonly used was determined by the late

J. J. Atkinson, Government Inspector of Mines of England. The value of this coefficient of friction is .0000000217. That is, the pressure required to overcome the average friction on each square foot of rubbing surface in a mine where the velocity is one foot per minute is .0000000217 part of a pound.

Q. 229. What pressure is required to overcome friction in producing an air-current 400 feet per minute in an entry 6 by 6 feet sectional area and 6,000 feet long, and what will be the reading of the water-gauge?

A. The rubbing surface of this airway is $24 \times 6{,}000 = 84{,}000$ square feet. The total pressure required to produce the ventilation is the continued product of the coefficient of friction, the rubbing surface and the square of the velocity, or $.0000000217 \times 84{,}000 \times 400^2 = 291.648$ pounds. But as there are 36 square feet sectional area, the pressure per square foot is $\frac{291.648}{36} = 8.1+$ pounds, so the reading of the water-gauge is $\frac{8.1+}{5.2} = 1.55+$ inches.

Q. 230. What are the advantages of splitting air-currents in a mine?

A. In ventilating a mine, it is always desirable to reduce the friction of the air-current to a minimum, so as to supply an abundance of fresh air to the miners in the most economical way. The air that passes from the downcast shaft is distributed in splits to the various working parts in proportions varying with their needs, so that each split becomes as little contaminated as possible with the gases and other impurities that originate in the mine. The length of the airway for each part of the mine is thus shortened and the friction is thereby reduced. As the area of the air-passages becomes greater, the velocity of the current is correspondingly lessened, and the friction in the mine is therefore reduced as the square of the velocity decreases. By thus splitting the current, fresh air can be supplied to the working faces in each part of the mine, a larger volume can be supplied with the same working pressure, each district may control its own circulation, and in this way an explosion that may occur in one part of the mine is less liable to be transmitted to other parts than when one current ventilates the whole property.

CHAPTER XIII.—ACCIDENTS IN MINES.

LESSON XXIII.

Q. 231. What may be said about accidents in coal mines, and how does their frequency compare with accidents in other mines?

A. Accident statistics based on the tonnage of mines show that for about every 200,000 tons of coal produced two men are injured and one life is sacrificed, and out of every 1,000 men employed in mines about three are injured every year. It is somewhat difficult to get an accurate record of all the accidents, but from the most reliable ones at hand it is safe to say that the number of fatalities becomes less as the laws become more rigid and a more intelligent and better educated class of men are employed at the work. This is the natural result of skill and experience, although increased depth of mines and more rapid hoisting have made the work more hazardous year after year; and the safety of life in our mines compares favorably with that of European countries. The greatest danger occurs in bituminous mines and in some of the anthracite regions where the seams are thick and highly inclined. In iron mines, accidents are only about one-third as numerous as in coal mines, while in the mining of the precious metals there is comparative safety, since injuries rarely occur in them, except through gross carelessness.

Q. 232. How do accidents occur in mines through carelessness?

A. Fully twelve per cent of all mine fatalities comes from crushing by cars in the haulage-ways where obstructions have been left on the track, or where the cars are forced together through carelessness. Sometimes an accident occurs from a brake being insufficient to hold the load on an incline, from a mule falling under the cars, or from there being insufficient illumination to see danger ahead. The roadways should always be kept clear, and made wide enough for persons to step aside to allow a loaded train of cars to pass them without danger to anyone. Accidents sometimes occur from the hoisting machinery breaking, or from the cable severing through too

long and constant use. When horse-power is used for winding, the whim may give way as a loaded cage is coming up the shaft, in which case the surface appliances, the cage, the shaft lining and the timbers at the bottom may be destroyed. Accidents also sometimes occur from materials falling down the shaft, and from too venturesome men falling into it. To prevent such dangers, the cars should never be filled so full that the jar of the hoist will cause any lumps of coal or rock to fall off, and no mine should ever be operated without proper gates at the landings to protect anyone from stepping into the shaft. Miners should never step under a descending cage, but should use the passage-way around the bottom of the shaft in passing from one side of the mine to another.

Q. 233. How do accidents occur from falling roof, and in what way does this danger vary with atmospheric changes?

A. The roof of some mines is composed of solid rock that offers perfect protection to all who travel underneath, and accidents from falling material do not occur in such. But when the roof contains seams and is composed of shaley layers, the rock is broken from the enormous weight which it sustains and frequently falls into the entries, roadways and rooms without previous warning. Indeed, it is often difficult for the miner to detect the indications of immediate danger. These can only be gotten from experience about a mine, and from the sound emitted when the overhead rock is struck with a pick. If the sound is dense, there is probably no danger, but if it is more or less sonorous, thus indicating separation of the layers or open cavities, there is danger ahead. With such a roof, caution should be exercised in passing under it until the danger is removed by a thorough system of timbering. The falling of roof depends to a large extent on the water which it absorbs. Atmospheric moisture is condensed in coming in contact with the interior of a mine that is colder than the air from the outside, and this action is greatest in shallow mines during the summer months, for the reason that the strata of such are colder than those of deep ones, and atmospheric vapor in summer being greater than that in winter is more readily condensed. Hence there is more danger from falling roof in summer than in winter. Likewise there is more danger at night than during the day from rock falling near the opening of a shallow mine, because the strata become colder and the condensation is greatest at that time.

Q. 234. Mention some of the dangers that may arise from blasting, and state what precautions should be taken in working a gaseous and dusty mine.

A. Firing of shots is always a source of danger in mining, even under the most approved methods. Iron and steel tools are no longer used in charging and stemming, and the firing of shots is now conducted in such a manner that accidents from premature blasts are generally the result of carelessness. Coal-dust is replaced by clay or other inert material for tamping, and no one now attempts to reopen a hole that failed to be fired. The subject of blow-out shots has for years received the careful attention of investigators on account of the many serious explosions that have arisen from their flame and burning particles in igniting the fire-damp or coal-dust of a mine. The substitution of high explosives for powder and the firing of shots by electricity in gaseous or dusty mines have prevented many serious disasters. The prohibition of loose powder in gaseous mines and the sprinkling of the roadways where much dust is afloat in the air have materially diminished the number of accidents. Careful inspection of the roof, thorough ventilation with proper velocity of the air-current, care in the use of powder, removal of dust or allaying it by sprinkling, skillful charging and stemming to prevent blow-out shots, together with the use of high explosives and electrical means of firing are the precautions that offer the surest safeguards against accidents.

Q. 235. What intellectual remedies can be applied to prevent accidents in mines?

A. In order to prevent accidents in mines, there must be an ever present realization of the impending dangers and the caution necessary to prevent them. The miner, by his long experience underground, gradually becomes oblivious to his surroundings, and so grows careless of the avoidable sources of danger. Doubtless many charges of carelessness where accidents occur are unjust to the miner, because in his work new problems may suddenly arise that require solution, which his education and experience do not supply. The remedy for these dangers must come through legislation, education and wise supervision; and until men willingly obey the laws, post themselves on all matters pertaining to their profession and follow the direction of skilled foremen in charge, accidents in mining cannot be entirely prevented. The laws should be form-

ulated in justice to both operator and miner, all precautionary means announced and vigorously enforced, and any serious offender should be discharged from the service of the company, no matter how slight the offense or how urgent his appeal for retention.

Q. 236. What is the best method of resuscitating a man who has been overcome with the poisonous gas of a mine?

A. Whenever a man has been overcome with the foul gases of a mine, he should be promptly removed to a point where there is pure air. His clothes should then be loosened from the neck and chest and cold water applied to the face. Artificial respiration should be induced by moving the arms forward and backward, so as to expand and contract the chest in each operation. The warmth of the body should be kept up by rubbing it and by applying hot flannels over the stomach, arm-pits, thighs and soles of the feet, while the circulation may be strengthened by applying mustard plasters over the heart and around the ankles. It is well to stimulate the lungs by holding a bottle of weak ammonia near the nose as inspiration takes place; and, upon the restoration of breathing, a stimulant, like wine, brandy or coffee, may be administered with advantage. The patient should then be removed to his home and kept quiet until fully recovered.

Q. 237. In case of an accident in which a miner receives a wound severing an artery, what would you do to prevent hemorrhage?

A. In preventing hemorrhage, it is necessary to bear in mind that the blood is forced outward through the arteries by the action of the heart, and so it is useless to try to check bleeding by simply binding up an arterial wound. The blood-current itself must be stopped before the wound is reached. To do this, put a compress or pad over the artery on the side toward the heart, with a handkerchief placed around the arm or leg, and draw the ends sufficiently tight, or twist the handkerchief with a stick put through it until the blood ceases to flow. Should the wound be on the front of the scalp, place the compress directly in front of the ear, and if on the back of the head, place it behind the ear. If these do not overcome the bleeding, a similar bandage should be placed about the opposite side of the head and securely fastened by tying, when the blood should cease flowing. The final prevention of hemorrhage can only be effected by closing the ends of the artery, which will be done by a physician as soon as he arrives.

CHAPTER XIV.—MINE SURVEYING.

LESSON XXIV.

Q. 238. What is mine surveying, and what are the duties of the person in charge of this work?

A. Mine surveying is the art of making such underground measurements as will determine the shape, dimensions and relative position of the different parts of a mine, and their relation to fixed objects on the surface. In the discharge of his duties, the mine surveyor or engineer is frequently called upon to make an accurate outline determination of the property and its topographical features, including the position of buildings, trees, streams and all other natural or artificial objects that characterize it. All improvements, like the building of roads and laying out railways, should be under his direction, and he must also be able to plat his notes accurately and construct the necessary maps and blue prints that are used in developing the property and in keeping its interior boundaries within the limits controlled at the surface. The larger companies employ a resident engineer for this purpose, but the smaller ones secure the services of a surveyor or engineer only occasionally to make the necessary maps required by law. Every superintendent or mine foreman should be capable of doing this work, and should provide himself with the instruments required for it.

Q. 239. Describe the chain, steel tape and pins used in making a survey.

A. For measuring distances in surveys, a steel chain is sometimes used. This is either fifty or 100 feet long, and consists of one-foot links with D-shaped handles at each end. At a distance of each ten links, a brass tag is hung from the joint, the first having one prong, the second having two, etc., the number of prongs indicating the number of ten feet distances from the zero end of the chain. Chains are liable to be stretched, and when a fraction of a foot is to be determined by them, it must be measured with a rule for the purpose. For these reasons chains are going out of use : nd being

replaced with steel tapes that range from fifty to 500 feet in length. These tapes are marked at each foot, are divided into tenths of a foot, and at every five feet are countersunk figures indicating the distance from the zero end. They terminate in D-shaped brass handles, are more convenient to use than chains and are wound on small wooden reels when not in use. Chains and tapes should be tested frequently for their accuracy and kept in adjustment by comparing with a standard distance that can be laid off on a smooth surface when the measures are new. The pins used in surveying are made of soft steel, are from fifteen to eighteen inches in length and terminate in a ring handle at one end, while the other is sharpened so as to be stuck easily into the ground. A set consists of eleven pins. In beginning the measurement, a pin is stuck into the ground, and when the front chainman has placed the eleventh pin, the back chainman comes forward with the ten pins he has picked up and records in his note book the distance thus measured, which is ten times the length of the chain or tape used. The work of measuring continues in this manner until the whole distance has been passed over and all necessary notes recorded.

Q. 240. Give a brief description of a compass and transit, and state wherein the latter is more accurate than the former.

A. A compass consists of a magnetic needle suspended on a pivot, so arranged that it can swing freely in a horizontal plane. This needle is enclosed in a metallic case having a glass over it and a graduated circle underneath it. Sights are placed on opposite sides of the center. They are sometimes made firm and sometimes hinged so as to fold over on the glass. One of these, called the north sight, has an aperture in which is suspended a vertical wire, while the south sight has a vertical slot with several small circular holes to which the eye is placed when sighting. The dial is divided into 360 degrees, and is marked with zero at the north and south sides, while ninety degrees are at the east and west quadrants. Compasses are sometimes provided with verniers for measuring accurately fractions of a degree in horizontal measurement, and when used in a mine they are commonly set on a tripod, or are supported on some solid object while the needle comes to rest. The compass is not provided with sufficient attachments to do accurate work, and can only be used in getting approximate results. It should never be

used in making a survey of a large mine, or where its needle is likely to be deflected by local attraction. Transits are made with double horizontal circular plates which nearly touch each other, the upper one being free to revolve completely around. These plates are provided with a vernier, while to the upper one is attached a telescope that is supported by uprights. This telescope is short and can be swung completely around in a vertical plane, so as to be used easily in taking front and back sights, without changing the clamp on the plates. When the telescope is too long for thus swinging completely over, the instrument is called a theodolite, and is provided with a vertical graduated circle for measuring vertical angles. Transits that have this vertical graduated circle are known as transit-theodolites. These instruments are provided with leveling attachments set at right angles to each other on the horizontal plates, and those of the theodolite variety usually have a leveling adjustment attached to the telescope. The transit is the only instrument that can be used in measuring angles with great accuracy. By using a transit, horizontal and vertical deflections can be measured with equal ease, and the greatest accuracy can be secured without considering the needle. Hence for all important mine surveys, a transit only should be used.

Q. 241. What is meant by declination of the magnetic needle, and how can a true meridian be found?

A. A true meridian is a line which, if produced, would pass through the north and south pole of the earth. The direction of a magnetic needle does not usually coincide with this, but takes the course of the magnetic meridian, which differs somewhat from a north and south line. The angle between these two directions is the declination* of the needle for the place of observation. The true meridian can be determined approximately by noting the direction of the shadow cast by an object at ten o'clock in the morning and at two o'clock in the afternoon, and then bisect the angle of these two directions. This method, which was employed by the Romans in laying out their cities, gives a very good approximation to the true meridian when it is carefully executed, although it is absolutely

* The term variation of the needle is sometimes used in place of declination, but this should be reserved for the irregular, diurnal, annual and secular changes in declination.

correct only at the time of the solstices, on June 21st and December 22d. The most accurate method, however, is by observing the North Star or Polaris as it revolves around the north pole in the heavens. This star is about one and one-third degrees from the pole, and passes the meridian twice in a little less than twenty-four hours. When it is on the true meridian, it is in a direct vertical plane with the star Alioth, which is the first in the tail of the Great Bear or Dipper. This plane or meridian can be determined when these stars coincide with the vertical line of a plumb-bob. It can be more accurately determined by using a transit or theodolite and turning the telescope until the two stars come in the vertical plane, when its direction can be staked out as a true meridian.

Q. 242. How should the survey of a mine be made to determine its outline and topography?

A. All lines bounding property are referred in direction to the true meridian. Beginning then at one of its corners, the transit is set directly over the stake by means of a plummet. The instrument is adjusted and the telescope turned along a boundary line, which is determined by the foresight-man setting up a flagpole at the next corner. The direction and distance to this are now ascertained and recorded, and the transit is then removed and set up over the second station. A back-sight is taken to determine that no error has been made, and the telescope is then turned in the direction of the second course, as shown by the flagpole which is now placed at the third corner, and its direction and distance likewise determined and recorded. In this manner every boundary line of the property is ascertained, the flagpole for the last reading always being located at the place of beginning. From a survey thus conducted, the exact area of the property can be ascertained and an accurate map made of it. In determining the topography, it is well to divide the surface into squares ranging from 100 to 500 feet on a side, and then by means of a transit-theodolite or a level set at convenient stations, the elevation of each corner of the squares is read on a leveling rod carried by a fieldman and placed at each station. All points above a datum-line are recorded as positive elevations and those below it as negative. From notes thus made, the contour lines representing equal elevations, and all other important information, can be plotted.

LESSON XXV.

Q. 243. Describe the best method of carrying a survey down a mining-shaft.

A. Carrying a survey down a shaft, or establishing in a mine a station and direction-line for reference, requires the most skill and patience of all the work of the surveyor or engineer, and to be of value it must be done with accuracy. One of the best methods of doing this is by the use of two copper wires suspended from the top of the shaft. Copper wire is used because it can be very small and is not as much affected by air-currents as a hemp cord and does not contract when wet. These wires are suspended from points in the upper corners of the shaft as far apart as possible, in a direction that corresponds with the underground passage-way, and at a short distance from the shaft in this line, a stake is placed as a point of reference for all underground measurements. On these wires plummets are attached that weigh five or six pounds, and these are hung in buckets of water or oil to keep them from swaying. The wires are carefully examined from top to bottom of the shaft to see that they are free, and the distance between them in the mine is measured to be more certain of their freedom to swing. The lower ends of these wires are illuminated with reflectors, while a white background is placed behind them to make them appear more distinct. Their direction is now the same as the line above ground, and they therefore make the same angle with the meridian as does that line. A distance from one of the suspended wires is now laid off on this underground line equal to the distance between the same wire and the station at the surface, and an exact point over it is established by means of a plumb-bob. This station is directly underneath the reference station at the surface, while the base-line determined from the suspended wires coincides in direction with that at the surface. From this underground station and direction-line all parts of the underground survey are determined.

Q. 244. How are underground stations established and used in making the survey of a mine?

A. In making the survey of a mine, it is necessary to establish stations throughout the underground passages that can be used as points of reference in plotting the notes. In selecting these stations, it is always well to use the smallest number consistent with the details desired, because a large number not only prolongs and renders more tedious the work, but the fewer the number of stations the less are the chances for error. Stations should always be established in the roof when it is possible to do so, because they are then less liable to be moved, destroyed or covered with the dust and debris of the mine. They must not only be as far apart as possible, but so located that the transit can be placed under them and the distance between them can be easily measured. At each station a vertical paint mark should be drawn on the side of the opening to call attention to the place, while a circular, square or triangular figure is painted around the center of the station and its number designated thereon. At the exact point of the station, a nail, screw or other accurate means of location is used, from which the plumb-bob can be fastened and swung. In conducting the survey, the exact point underneath the station is generally marked on the floor, so that the transit can be set directly over it by using the plummet underneath. In large mines where several corps of surveyors or engineers are engaged, stations common to each are marked with a distinguishing number of each corps, so as to identify such points when plotting their notes.

Q. 245. Give a brief description of the method of conducting an underground survey, and state how the notes should be kept.

A. Making the underground survey, after the stations have been established, consists in determining the direction and length of each line, and the making of such side observations as will enable the surveyor or engineer to plot accurately the width of every passage-way and room in the mine. In determining the courses, it is best to dispense with the magnetic needle and measure the angles by front and back sights when a transit is used, because the surveyor or engineer can never rely on his needle in places where iron ore may occur. In recording the angles and in making the linear measurements, the width of the entries and the distance between rooms should be determined. The dimensions and direction of the rooms, and the size of their entrances when they have been made narrower on account of

poor roof, should always be determined. The location of stables, air-shafts, break-throughs, overcasts and undercasts, and all other important parts of the mine should not only be carefully determined, but also recorded in the notes of the survey. These notes may be kept in various ways, and they should be dated and arranged so that when additions are made after a long time, the note-book will be a systematic record of the workings of the mine. They should state between what stations the observations are taken, the direction and length of each line, and the width of the entry and thickness of the coal at each station. Whenever any appreciable variation is detected in the width of the entry or thickness of the seam, such should be noted. The place where each room is turned, its direction, size and thickness of pillar and entrance opening should be taken down. In this manner the notes of every other line and measurement may be recorded, and everything should be sufficiently complete to enable the surveyor or engineer to construct an exact map of every detail of the underground workings.

Q. 246. Describe the curves used in constructing surface and underground railways.

A. The curves used in the construction of railways are always laid out in a scientific manner, and the more important ones, like those where rope-haulage is used, should always be put in with the aid of a transit. The surveyor or engineer is frequently called upon to lay out the lines of railway on the surface, and often to plan for those underground. Railway track consists of straight lines united with curves, but there are limits of curvature prescribed for all roads which should not be exceeded. These curves are simple, compound and reversed. Simple curves are arcs of circles; compound curves are circular arcs of different radii, so joined as to gradually pass from a straight line to the greatest curvature; and reversed curves are continuous ones made up of two or more simple or compound curves described in opposite directions. The curve which is used as a basis of comparison is called a one-degree curve, and is that which has an arc of 100 feet joined by radii that enclose an angle of one degree. So in general, for any other degree curve, the arc is always 100 feet, while the degree of curvature is the angle subtended between radii by this distance. The radii for a one-degree curve are 5,729.65 feet; for a two-degree curve they are 2,864.93 feet, and for a three-degree curve they are 1,910.08 feet.

Q. 247. How can a railway curve be laid out with a transit?

A. A railway curve may be laid out with a transit by determining points in its arc through measurements of its chords. Beginning with the last station on the straight line from whence the curvature begins, set the transit in the direction of the straight line continued as a tangent, and from this lay off an angle equal to one-half the degree angle of the curve used. Then measure 100 feet in its direction and set a stake which will be the first point in the curve. Then continue to lay out each of the other points in the curve by increasing the angle of deflection by the same amount each time, and measure for the second point 200 feet, for the third 300 feet, and so on until the entire work is completed. The several points thus determined will be on the desired curve. Although this method is not absolutely exact, it gives for all ordinary purposes results that are practical for short curves of small angle. A better method of determining points on a railway curve is by tangent deflections. These are perpendicular distances from the tangent to the curve at its end opposite the point where the tangent begins. Imagine a line drawn from the point of tangency making with the chord of the arc an angle equal to the degree of the curve. Then, owing to the similar triangles thus formed, the radius of the circle is to the chord of the arc as this chord is to twice the tangent deflection; or the tangent deflection is equal to the square of the chord divided by twice the radius of the circle. In laying off the points of curvature, set the transit where curvature begins and measure on the tangent continued a distance equal to the perpendicular of a right angle triangle having for its hypothenuse the chord, and for the acute angle one-half the degree of the curve. Then from this point measure at right angles toward the curve a distance equal to the tangent deflection. This point will be the first station on the curve. Set the transit at this location as a point of beginning and lay off a second station on the curve, pointing the telescope tangent to it by making the angle with the last tangent equal to the degree of the curve. Proceed likewise for each of the other stations. The stations thus determined will be exactly on the curve. Hence this method is especially satisfactory for railway location where great accuracy is required.

CHAPTER XV.—MAPS AND BLUE PRINTS.

LESSON XXVI.

Q. 248. What do maps and blue prints represent, and what instruments are necessary in preparing them?

A. The reproduction on paper of the angles, lines and distances of a survey, according to scale, is known as plotting. When these are all delineated, and the paper is mounted, a map of the property is the result. When the lines or angles are placed on tracing paper, and then a print of this is taken on sensitized paper, which is afterwards treated to remove the unaffected coloring salts, a blue print is the result. In this, white lines correspond to the black lines of the tracing, while the balance of the surface is blue. All maps and tracings are made to scale, which is generally 100 feet per linear inch for mines, but this varies with the object in view in doing the work, and the larger the drawing for a given property, the greater will be the accuracy with which it can be made. The necessary instruments required to prepare maps and blue prints are a draughting-board, T-square, protractor, scale, ruling-pen and a piece of plate glass as large as the limits of the paper. After stretching the paper on the board, it is fastened firmly with thumb-tacks or with mucilage in a position that is best suited to the requirements of the map. The T-square is used to draw parallel base-lines for making angular measurements on paper. These are laid off with a protractor, which is an instrument that is divided into degrees, and fractions of a degree around an arc so as to lay off any angle required. A scale is made of wood, ivory or steel, and is divided into inches and decimals thereof. The best ones are triangular, so as to bring an edge direct to the paper when making a measurement, while each side is divided in a different manner. The ruling-pen, although not absolutely indispensable, is much more convenient

and more accurate than an ordinary pen for tracing lines, and should always be used in map drawing. So also should India ink be used if the drawing is to be permanent. The plate glass is required to hold the tracing firmly against the sensitized paper while developing the blue print.

Q. 249. How can an outline map of property be plotted to scale from the field notes?

A. In beginning the map, select a point for the first station that will be well-located on the paper with reference to all the other stations and the boundaries of the property. Bring the T-square with its base against the draughting-board so that the edge of its arm passes through this point, and draw a fine pencil line along it. Place the base of the protractor against this line with its center at the station, and mark on the paper the degree of the first course, and then a line drawn through these two points will be the first line of the survey. From the first point lay off a distance on this line equal to the length of the first course, according to the scale used, and mark the point that terminates it. Then from this station draw another line in the same manner for the second course of the survey by using the T-square, protractor and scale. Continue this plotting by angles and measurements for each of the other sides of the property, when the last one will terminate at the place of beginning, if the survey and plotting have been done accurately. Each of these lines is drawn with a ruling-pen and India ink, and the light pencil marks are removed with an eraser. Around each station draw a very small circle to designate the termination of the line, and beside it place a letter to use in describing the survey. On one side of each line near its center should be placed the distance and on the other side the direction of the course. The whole map thus made should have a border drawn around it, and in a corner the scale of the survey should be placed for reference, while the name of the property and its location are lettered neatly across the top. Also in one upper corner draw a fleur de lis to represent a true north and south direction. Such a drawing constitutes an outline map, and is of service in describing the property and in determining its area.

Q. 250. Describe how a topographical map is prepared.

A. In preparing a map of a topographical survey, lay off the surface of the paper into squares with a light pencil, according to

scale from the field measurements. Then note on the paper as the datum or zero point, the place where the transit was first used, and at each intersecting line place figures that give the elevation or depression with reference to this, as shown in the field notes. These figures represent distances above or below an imaginary horizontal plane passing through the datum or zero point. Examine these figures with care, bearing in mind the configuration of the surface observed when making the survey. Then connect with a fine pencil the points of equal elevation with curved lines that conform to the surface, and interpolate where the lines should pass for points between numbers above and below this elevation. Continue this work until the whole surface has been gone over and all contour-lines drawn. Each line represents places of equal elevation and shows at a glance the configuration of the surface. All streams, buildings and roads, as well as cultivated and forest land, should be located on the map. After this has been executed in pencil, all contours should be traced with ink, elevations carefully noted and permanent objects properly recorded. As in the case of other maps, a border should be drawn around the property, its scale placed in the corner, a north and south direction-line placed near the top, and the name and location of the property lettered across it. A topographical map thus made is especially useful in deciding on a system of drainage.

Q. 251. How may a map of the underground workings of a mine be prepared?

A. After selecting a point of beginning for the map, draw a north and south pencil line through it, and from the point thus selected trace a pencil line in the direction of the course between the first two stations. On this, lay off the distance first measured in the survey, and with the scale adopted for the map, trace fine pencil lines that represent each side of the entries, showing their irregularities, position and size of shafts, airways, break-throughs and all other important parts of the mine that the side notes indicate. Likewise lay off the direction and shape of rooms with their entrances, and record in figures on the outline all distances measured. Draw a very small circle around each station and letter and number it. Continue this preliminary pencil work until all notes have been delineated on the paper. Then with a ruling-pen and a fine mapping-pen and India ink go over the work, tracing in every permanent line.

figure and symbol that should be recorded. When this has been done, remove all pencil marks, place a border around the map, note the scale, the north and south direction-line and letter the name and location of the property at the top. Such a map when properly made will show all working places in the mine, and can be mounted on canvass for permanent use.

Q. 252. Describe a method of preparing blue prints.

A. Instead of making the map heavy for permanent use, it is prepared on tracing paper when blue prints are to be made. This paper is thin and nearly transparent, made especially to allow the rays of light to pass through it. This is stretched on the draughting-board, and on it all the details of the map are recorded in exactly the same way as a permanent map is prepared. These lines and representations are then transferred to blue print paper which can be purchased already prepared, or can be made easily in a dark room from highly sized white note paper by dipping it into a freshly prepared sensitizing solution for the purpose. This contains one part of potassium ferricyanide, one part of ammonium citrate of iron, eight parts of distilled water, and to every ounce thus prepared, five drops of a ten per cent solution of ammonium bromide are added. The excess of this solution is removed and the paper dried, when it is ready for use. By exposing it to the light, these salts are caused to combine, when they form an insoluble blue compound resembling Prussian blue. The printing can best be done by placing the sensitized paper on the draughting-board with the tracing over it, held firmly in place by a sheet of plate glass sufficiently large to cover the map. It takes two or three times as long to print or to produce the chemical change that takes place here as is required with silvered paper. When it has been completed, remove the paper from the board in a dark room and immerse it immediately in water to which a few drops of hydrochloric or citric acid have been added. Then wash it in five or six changes of clean water, which will remove all salts that are not affected by the light. The result will be a brilliant print showing white lines for the tracings upon a blue background. Dry and press the paper when it will be ready for use. Blue prints are valuable in studying the development of a mine, and are now used extensively in nearly all scientific professions where maps, designs, or illustrations are essential to the work.

CHAPTER XVI.—QUESTIONS FOR REVIEW.

On Lesson I.

1. What is the difference between notation and numeration?
2. Numerate or read 122,820.62.
3. How should the following be read: $24-18+22=21+7$?
4. What is the difference between multiplication and division?
5. Define the terms divisor, dividend, quotient and remainder.
6. Explain how to divide 201,352 by 108.
7. How many cars holding 30 tons each are required to carry 1,200 tons of coal?
8. How many miners averaging 4 tons each daily are required to mine 450 tons of lump coal per day, if the waste and screenings amount to 230 tons per day?
9. If the circumference of a wagon wheel is 12 feet, how many revolutions will it make in traveling a distance of 3 miles?
10. If the daily receipts of a manufacturing company are $1,020, and the daily expenses are $820, what is the net annual income?

On Lesson II.

11. Explain what is meant by the fraction $\frac{3}{8}$.
12. Define a proper and an improper fraction, and state how the latter is reduced to a mixed number.
13. What is the effect on the value of a fraction if both numerator and denominator are multiplied or divided by the same number?
14. Numerate or read .120; .080; and .0003.
15. Reduce $\frac{3}{5}$ to a decimal.
16. Reduce .250 to a common fraction.
17. What is the sum of $\frac{1}{3}$ and $\frac{3}{4}$?
18. Multiply 2.07 by .22.
19. Divide $\frac{2}{3}$ by $\frac{5}{9}$.
20. When $\frac{2}{3}$ of a ton of coal is worth $1.06, what are 3 tons worth?

On Lesson III.

21. In what ways can 12 per cent be expressed?
22. What is 8% of 3,000?

23. What per cent of 1,800 is 1,440?

24. 72 is 3% of what number?

25. A farm sold for $5,250, which was 5% more than it cost; what was its cost?

26. 9,700 is 3% less than what number?

27. What is the ratio of 2 to 3?

28. The ratio of 8 to 16 is as the ratio of 100 to what number?

29. When 20 pounds of sugar sell for $1.00, what are 35 pounds worth?

30. If 3 men can mine 24 tons of coal in 2 days, how many tons of coal can 4 men mine in 3 days?

On Lesson IV.

31. What is the square of 9?

32. What is the rule for squaring a number consi ting of two figures?

33. What is the cube of 4?

34. What is the rule for cubing a number consisting of two figures?

35. How many integers will there be in the square root of a number containing six figures? How many integers in the cube root of a number containing nine figures?

36. What is the square root of 961?

37. What is the square root of 5,329?

38. What is the cube root of 42,875?

39. What is the cube root of 531,441?

40. How can you prove the results are correct for square and cube root?

On Lesson V.

41. Define and illustrate by drawings what are meant by isosceles triangles, trapeziums, parallelograms and parallelopipedons.

42. The base of a right angle triangle is 6 inches and its hypothenuse is 10 inches. What is its perpendicular?

43. What is the diagonal of a square whose sides are 20 inches?

44. What is the circumference of a pulley whose diameter is 30 inches?

45. What is the diameter of a cylindrical boiler whose circumference measures 25.1328 feet?

46. What is the side of a square whose area is 196 square inches?

47. How does the rubbing surface of two airways of the same length compare when the cross section of one is 6 by 6 feet, and that of the other 4 by 9 feet?

48. What will it cost to carpet a room 24 feet long and 18 feet wide with carpeting worth $1.25 per yard?

49. How many feet of lumber in an inch board 14 feet long by 18 inches wide?

50. The base of a rhomboid is 20 inches and its area is 220 square inches. What is its altitude?

On Lesson VI.

51. What is the area of a triangle whose base is 12 inches and altitude is 10 inches?

52. If the area of a trapezoid is 120 square feet, what is its altitude, when the parallel sides measure 10 and 14 feet respectively?

53. What is the area of a trapezium whose diagonal is 40 inches, when the perpendiculars upon it are 10 and 18 inches respectively?

54. How would you determine the area of a piston head when its diameter is given?

55. What is the surface of a globe whose diameter is 20 inches?

56. The base of a triangle whose area is 144 square feet is 16 feet. What is the base of a similar triangle whose area is 324 square feet?

57. What are the sides of a cube whose volume is 2,744 cubic inches?

58. What is the altitude of a prism whose base contains 20 square inches and whose volume is 240 cubic inches?

59. Determine the volume of a sphere whose diameter is 12 inches.

60. State the mathematical relation existing between the volume of similar solids when the ratio of their corresponding dimensions is given.

On Lesson VII.

61. Define the terms matter, molecule, atom, force and gravity.

62. What is the difference between mass and weight of a body? What is meant by momentum, and of what is it a measure?

63. Give the laws of gravitation (*a*) for bodies within the earth's surface, and (*b*) for bodies outside the earth.

64. If a body weighs 100 pounds on the earth's surface, what should it weigh at a point half-way to the earth's center?

65. What should be the weight of a body 3,967.5 miles above the earth, if it weighs 1,000 pounds at the earth's surface?

66. What is meant by specific gravity? What by center of gravity?

67. If a cubic foot of rock weighs 325 pounds, what is its specific gravity?

68. What is meant by the moment of a force, and how may it be used in determining the stability of bodies?

69. Two bodies weighing 100 and 200 pounds respectively are held rigidly 100 inches apart. At what point between them can a single force of 300 pounds be applied that will hold them in equilibrium?

70. What is meant by uniform velocity, and what kind of a force produces it? What by uniformly accelerated velocity, and what kind of a force produces it?

On Lesson VIII.

71. If a train goes 108 miles in three hours, what is its average velocity?

72. With what velocity will a body be falling at the end of 10 seconds, if it starts from a state of rest, and is acted upon only by gravity?

73. How far will a body fall in 10 seconds, if it has no initial velocity, and is acted upon only by gravity?

74. A body is projected vertically upward with a velocity of 96.48 feet per second. How high will it rise?

75. How much work is done in raising 1,000 pounds ten feet high? Is the amount of work independent of the time required, or does it in some way depend upon it?

76. How many horse-power are required to raise 10,000 pounds 330 feet against gravity each minute of time?

77. Distinguish between potential and kinetic energy, and give a formula that expresses each.

78. Can a machine create energy? What is the beneficial work to be secured from any machine in terms of the work required to operate it, and the work required to overcome its friction?

79. Define and illustrate by drawings the three classes of simple levers.

80. Give the law for static equilibrium of any lever in terms of its power, weight, power arm and weight arm.

On Lesson IX.

81. What power acting on a lever arm 100 inches in length is required to balance a weight of 800 pounds suspended from the other end of the lever four inches beyond the fulcrum?

82. A wheel-barrow and its load weigh 400 pounds, and their center of gravity is two feet from the axle. What force must be applied to lift the handles, if the distance between the axle and its point of application is six feet?

83. What force must be applied in a system of two compound levers to balance a weight of 5 tons, if the weight lever arms are six inches long and the power lever arms are 120 inches long?

84. What power must be applied at the circumference of a wheel with forty inches radius to hold in equilibrium a weight of 800 pounds suspended from the circumference of its axle of five inches radius?

85. Give the law of equilibrium for pulleys expressing the relation between the power and weight.

86. What force must be applied to the rope of a tackle having one movable block of three pulleys, if the weight to be lifted is 700 pounds and one end of the rope is attached to the movable block?

87. The length of an inclined plane is twelve feet and its altitude is two feet. What force acting parallel with its surface is required to hold in equilibrium a weight of 1,200 pounds?

88. How many units of work are expended in moving a body weighing 500 pounds up an inclined plane twelve feet long and two feet high?

89. What power must be applied to a wedge twelve inches long and two inches thick to sustain in static equilibrium a resistance of 5,000 pounds?

90. The end of a lever arm attached to a screw makes a circumference of seventy-two inches, and the distance between the threads of the screw is one-half inch. What power must be applied at the end of the arm to hold in equilibrium on the nut a weight of 3,000 pounds?

On Lesson X.

91. Define the terms brattice, buntons, creep and squeeze.

92. Define the terms lagging, longwall, square-set and sump.

93. Define the terms after-damp, anemometer, black-damp and fire-damp.

94. Define the terms motive column, regulator, water-gauge and white-damp.

95. Define the terms bonnet, cage, chute and fan.

96. Define the terms indicator, sheave, tail-rope and whim.

97. What is a mine foreman or pit boss?

98. What qualities should be possessed by a mine foreman or pit boss?

99. What should be the qualifications of a mine foreman or pit boss?

100. What are the duties of a mine foreman or pit boss?

On Lesson XI.

101. What is the Iowa law concerning the mapping of mines?

102. What does the Iowa law require in way of distinct outlets for each seam of coal that is worked?

103. What does the Iowa law require in way of fans or furnaces for ventilation, and ladders and hoisting appliances for the miners?

104. How much time is given an operator to open the necessary outlets of an Iowa coal mine, and how many men can be employed before these are constructed properly?

105. How much air does the law require for each man, horse and mule employed in an Iowa coal mine? How shall this be circulated through the mine, and what means can be employed for this purpose?

106. What are the duties of an Iowa mine inspector when he finds an insufficiency of air, or the mines being worked under unsafe conditions?

107. What method of communication between the bottom and top of shaft- or slope-mines is required by the Iowa law when the voice cannot be heard distinctly? Also, what safety appliances are required on machinery used in lowering and hoisting the men from a mine?

108. What kind of engineers does the law specify can be placed in charge of the engines used in and about the coal mines of Iowa?

109. What does the Iowa law specify concerning scales, weigh ing coal and keeping an accurate record of each miner's account?

110. What is the method of paying miners in Iowa, and on or before what dates must a cash settlement be made?

On Lesson XII.

111. What is the penalty for an owner, weighman or check-weighman in case of attempt to defraud a miner on the correct weight of his coal?

112. What is the penalty for obstructing air-courses, disturbing machinery, disobeying orders relating to the safety of a mine, or doing any act whereby the lives of miners are sacrificed or their health impaired?

113. In case the owner or operator fails to provide for safety of employes after twenty days' notice by an Iowa mine inspector, what should be done?

114. What kind of mine illuminating materials are permitted under the Iowa law?

115. What is the penalty in Iowa for selling adulterated or impure oil to be used in illuminating coal mines?

116. What is the method of having mine illuminating oil tested in Iowa?

117. For mines of what output is it necessary to have certificated mine foremen and hoisting engineers, and what provisions are made for filling vacancies caused by discharge, resignation, or disability of any certificated person?

118. What board issues certificates of competency to mine foremen, pit bosses and hoisting engineers in Iowa, and what other duties are imposed on this board?

119. What are the requirements for and what is the method of securing a certificate as mine foreman, pit boss or hoisting engineer in Iowa?

120. What is the penalty for employing an uncertificated mine foreman, pit boss or hoisting engineer for mines provided for in Chapter 82 of the acts and resolutions of the Twenty-eighth General Assembly of Iowa?

On Lesson XIII.

121. What is an explosive, and in what way does it develop its power?

122. What would be the characteristics of an ideal explosive for use in mining bituminous coal?

123. Give the composition of blasting powder, and explain in what way a change in this alters its properties.

124. What are the products of a powder explosion? Are any of these especially injurious or dangerous in a mine?

125. What is the force developed in the explosion of powder?

126. Describe a blow-out shot, and explain fully what causes it.

127. What are the dangers that may result from blow-out shots?

128. How would you proceed in firing shots to have the least danger from accidents?

129. Name some of the high explosives used in coal mining, and state why they are safer than powder.

130. Why should high explosives be discharged by electricity in a dusty mine generating gas, and why are they not more frequently used in coal mining?

On Lesson XIV.

131. What other names are applied to the room and pillar method of mining?

132. When is the room and pillar method to be preferred for coal mining?

133. Where should a mining-shaft be located to afford the greatest advantage in working the property?

134. What is meant by single, by double and by triple entries, and for what is each used?

135. Why is it desirable to have large shaft pillars for all classes of mines?

136. What should be the size of shaft pillars for a nine-foot seam of coal, 729 feet deep?

137. Describe the development of a room and pillar coal mine, including the drawing of pillars.

138. What can you say of panel working, and for what kind of coal mines is it especially used?

139. What is the usual size of roadways and rooms in the bituminous coal mines of the central west, and upon what do the dimensions depend?

140. What factors should determine the size of pillars for bituminous coal mines, and under what conditions should the pillars be especially large?

On Lesson XV.

141. Under what conditions may it be desirable to allow the pillars of a coal mine to remain for some time?

142. Why should the pillars of a coal mine generally be removed as quickly as possible?

143. Describe how you would approach a body of water or gas in a mine and use the necessary precautions that will insure safety.

144. Why are good roads essential to the successful management of a mine?

145. In what way should the track be laid in a mine to secure the best results?

146. Explain the nature of an explosion in a coal mine, and the conditions under which it may take place.

147. How may coal-dust affect the results of a gas explosion in a mine, and how does the ventilation increase its intensity?

148. In what way may a small mine fire be put out without using water or carbonic acid gas to extinguish it?

149. Under what conditions should a mine be flooded with water or carbonic acid gas to extinguish fire?

150. How would you proceed to reopen a mine after a fire or an explosion and observe the necessary precautions to avoid accidents?

On Lesson XVI.

151. For what kind of coal mines is the longwall method of working best adapted?

152. What are some of the advantages of longwall mining?

153. Can the longwall method be applied as well to mines with a weak and brittle roof as to those with a strong and flexible roof?

154. Give a brief description of the general process of longwall mining for seams of coal that are overlaid with a strong and flexible roof.

155. Give a description of the longwall process as it is applied to some of the thin seams of coal in the central west.

156. Distinguish between longwall advancing and longwall retreating, and state under what conditions the latter process is to be preferred.

157. Describe the longwall process as applied to seams of coal with a weak and brittle roof.

158. How is the coal removed from the working faces in some of the thin seams of the central west, and what becomes of the refuse of the mines?

159. Describe the longwall process of driving entries and making roadways.

160. What is the size of entries and roadways for longwall mines, and why is it desirable to remove enough rock from them to furnish the gob required to prevent the roof from falling as much as possible?

On Lesson XVII.

161. What is meant by undercutting or holing as applied to coal mines, and what objections are offered to machines for this work?

162. How are the working faces kept in a safe condition and the passage-ways kept clear in a longwall mine?

163. Upon what does the method of building walls and packing the gob in a longwall mine depend?

164. Describe the building of entry walls and supporting the roof in a longwall mine.

165. State how spontaneous combustion may originate in a mine. What are the causes that may favor its production?

166. How would you proceed to prevent spontaneous combustion in a mine when there are indications that it may originate at any time?

167. Describe the method of haulage in a longwall mine.

168. In what way may water do harm in a coal mine?

169. What is the simplest drainage system of a longwall mine?

170. Why should regularity and uniformity be observed in the development of a longwall coal mine?

On Lesson XVIII.

171. Which is the more destructive of life in mining, fires and explosions or falling of roof from insufficient timbering?

172. Can a creep or squeeze be prevented by timbering the area in which it occurs?

173. Describe the lining of a shaft with guide-planks, and state under what conditions this method of timbering is preferred.

174. How are shafts timbered when the lateral pressure is great and thorough protection is required?

175. Explain the method of timbering an ordinary slope for single-track haulage.

176. What is meant by the skin-to-skin method of timbering a mine?

177. How are the roadways and entries timbered for a system of double-track haulage?

178. What is the method of timbering a roadway or entry that only needs supporting overhead and on one side?

179. How should the props be set in the underground workings of a mine to give greatest protection to the miner, and yet afford economy to the operator?

180. What can you say about timber-drawing in a mine, and what are the dangers attending it?

On Lesson XIX.

181. What are the chief properties of marsh gas?

182. Why is it dangerous to fire powder in an atmosphere of marsh gas, where an instantaneous explosive can be used with safety?

183. What is meant by fire-damp, and what are the conditions under which it may occur in a mine?

184. Under what variations in composition is fire-damp ordinarily explosive? State what conditions may influence this range in per cent.

185. How is the air of mines tested for fire-damp?

186. What are the best oils to use in safety-lamps?

187. What is the origin of carbonic acid gas, and how can it be detected in the air of a mine?

188. What are the injurious effects of breathing carbonic oxide?

189. How does the condition of the weather effect the production of gases in a mine?

190. In what way are hydrogen sulphide, smoke and dust detrimental to the air of a mine?

On Lesson XX.

191. Enumerate some of the principles that govern the ventilation of mines.

192. What volume of air is required to ventilate a mine producing 250 tons of coal per day, and what should be the size of the main airway if considerable explosive gas is present?

193. The main airway of a mine is six by eight feet, and it is found that smoke passes through it at the rate of 550 feet per minute. What is the approximate amount of air being used?

194. Describe an accurate method of using the anemometer to determine the velocity of an air-current.

195. Why is it that in mines using only natural ventilation, the deeper shaft usually acts as an upcast in winter and downcast in summer?

196. What is the motive column of a mine 200 feet deep when the temperature of the downcast is 30 degrees and that of the upcast 100 degrees Fahrenheit?

197. Distinguish clearly the meaning of the terms pressure and power as applied to the ventilation of mines.

198. State how the water-gauge is used in determining the ventilating pressure of a mine.

199. Explain fully how the power producing the ventilation of a mine can be determined when the amount of air circulating through it and the reading of the water-gauge are known.

200. What horse-power is required to ventilate a mine using 50,000 cubic feet of air per minute, when the resistance shows a water-gauge reading of 3 inches?

On Lesson XXI.

201. How is a ventilating furnace constructed, and what conditions may change its efficiency?

202. In what way is the inflammable gas of a mine conducted around the ventilating furnace so as to prevent an explosion?

203. Upon what does the fire-grate surface of a ventilating furnace depend?

204. How can you determine the proper area for the fire-grate of a ventilating furnace?

205. What should be the dimensions of a furnace-grate necessary to ventilate a mine 900 feet deep with 150,000 cubic feet of air per minute, when the water-gauge resistance is 1.5 inches?

206. Describe the waterfall method of ventilation, and state under what conditions it is to be recommended.

207. When is an exhaust-fan to be preferred to a force-fan in ventilating a mine?

208. If a fan producing 60,000 cubic feet of air per minute makes 50 revolutions, how many revolutions must it make to increase the amount to 90,000 cubic feet per minute?

209. Why are fans more frequently used than furnaces for ventilating shallow mines?

210. Why do furnaces become relatively more efficient than fans as the depth of a mine is increased?

On Lesson XXII.

211. In what way does the pressure producing ventilation of a mine vary with the rubbing surface, when the velocity of the air-current remains constant?

212. Given two airways of equal length, one five feet square, and the other four by six feet. If the pressure required to ventilate the square airway shows a water-gauge resistance of 1.5 inches, what will be the pressure in the rectangular airway when it is ventilated with the same velocity of current?

213. In what way does the pressure producing ventilation vary with the area of the airway, when the velocity of the current and the rubbing surface of the mine remain constant?

214. Given two airways of equal length and equivalent rubbing surfaces, one five feet square, and the other circular. If the pressure required to ventilate the square airway shows a water-gauge reading of two inches, what will be the pressure required to ventilate the circular airway with a current of the same velocity?

215. What is the relation between the pressure required to ventilate a mine and the velocity of the air-current, so long as the area of the airway remains constant?

216. The velocity of an air-current in an entry five by six feet is 400 feet per minute, and the water-gauge stands at two inches. What is the pressure required to ventilate another airway four by seven and one-half feet sectional area of the same length, if the velocity of the air-current is 500 feet per minute?

217. Define the coefficient of friction as applied to ventilation, and give its numerical value.

218. What pressure is required to produce an air-current 500 feet per minute in an entry five feet square and 5,000 feet long? What will be the reading of the water-gauge?

219. Mention some of the advantages of splitting the air-current in a mine.

220. Show that the advantages of splitting the current are in accord with the laws of friction of air in mines.

On Lesson XXIII.

221. What do statistics show is the ratio between the number of accidents and the tonnage of coal mines?

222. Compare the frequency of accidents in coal and metal mines.

223. In what manner does carelessness contribute to accidents in coal mines?

224. What are the causes of falling roof, and how would you make an inspection to determine the danger from it?

225. How do atmospheric changes affect the safety of roofs?

226. In what way do accidents occur in blasting?

227. What is the best method of preventing explosions in gaseous and dusty mines?

228. Can any intellectual remedies be applied that will largely overcome accidents in mining? If so, what are they?

229. How would you resuscitate a miner who has been overcome with poisonous gas?

230. What means would you adopt to overcome hemorrhage from an arterial wound?

On Lesson XXIV.

231. What are the duties of the surveyor or engineer at all important mines?

232. How do companies operating small mines generally get their surveying done and maps prepared?

233. Describe the chain and steel tape that are used in surveying mines.

234. Give the method of measuring a line by means of a steel tape and pins.

235. Describe a compass and a transit.

236. Why is a transit preferred to a compass in making a survey?

237. What is meant by declination of the magnetic needle?

238. How can a true meridian be determined with accuracy?

239. How are the direction and length of boundary lines determined in making a survey?

240. Describe a good method of making a topographical survey.

On Lesson XXV.

241. How can a survey be carried into a mine?

242. Why are copper wires better than hemp cords in carrying down the survey?

243. What are underground surveying stations, and how are they located?

244. How are underground surveying stations ordinarily marked? How are stations marked that are common to two or more corps of surveyors or engineers?

245. Describe how an underground survey is conducted.

246. In what manner should the notes of a survey be kept?

247. What are simple curves? What compound curves? What reversed curves?

248. What is meant by the degree of a curve?

249. How are curves established by the method of chords?

250. How are curves established by tangent deflections?

On Lesson XXVI.

251. What do mining maps represent, and what instruments are essential in preparing them?

252. What is meant by plotting to scale, and how are the lengths of lines determined in this work?

253. Describe how to locate the boundary lines in plotting a survey.

254. Of what service is an outline map of mining property?

255. What is a topographical map, and what do the lines on it represent?

256. How are the contour lines determined in preparing a topographical map?

257. Describe how to prepare a map of the underground workings of a mine.

258. Why should all the working places be plotted to scale in preparing a map of a mine?

259. How may paper for blue prints be prepared?

260. What is the process of making blue prints, and for what are they principally used?

INDEX